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SPACE STATION EXPERIMENT DEFINITION: ADVANCED POWER SYSTEM TEST BED

FINAL REPORT

15 December 1986

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FINAL REPORT

16. Abstract

THE OBJECTIVE OF THIS EIGHT MONTH EFFORT WAS TO PROVIDE A CONCEPTUAL DESIGN FOR AN ADVANCED PHOTOVOLTAIC POWER SYSTEM TEST BED AND TO BETTER DEFINE THE REQUIREMENTS FOR ADVANCED PHOTOVOLTAIC POWER SYSTEM EXPERIMENTS. RESULTS OF THIS STUDY WILL BE USED IN THE DESIGN EFFORTS CONDUCTED IN PHASE B AND PHASE C/D OF THE SPACE STATION PROGRAM SO THAT THE TEST BED CAPABILITIES WILL BE RESPONSIVE TO USERS' NEEDS. CRITICAL PV AND ENERGY STORAGE TECHNOLOGIES WERE IDENTIFIED AND INPUTS WERE RECEIVED FROM THE INDUSTRY (GOVERNMENT AND COMMERCIAL, U.S. AND INTERNATIONAL) WHICH IDENTIFIED EXPERIMENTAL REQUIREMENTS. THESE INPUTS WERE USED TO DEVELOP A NUMBER OF DIFFERENT CONCEPTUAL DESIGNS. PROS AND CONS OF EACH WERE DISCUSSED AND A STRAWMAN CANDIDATE IDENTIFIED. A PRELIMINARY EVOLUTIONARY PLAN, WHICH INCLUDED NECESSARY PRECURSOR ACTIVITIES, WAS ESTABLISHED AND COST ESTIMATES PRESENTED WHICH WOULD ALLOW FOR A SUCCESSFUL IMPLEMENTATION TO THE SPACE STATION IN THE 1994 TIME FRAME.

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TABLE OF CONTENTS

Space Station Experiment Definition:

Advanced Power System Test Bed

Final Report

1.0 Introduction

This report is the conclusion of a six month study, funded by NASA-Lewis Research Center, to provide a conceptual experimental design for the testing, development, and evaluation of advanced photovoltaic power system technologies on space station, and to document experimental requirements. Six primary tasks were identified which when completed would provide the required information. Ford has completed effort on all of these tasks (summarized in Section 2 below) and presented the inputs to NASA-Lewis at the three month and six month reviews. This report summarizes the findings of work performed on each of the tasks, provides a program cost summary and gives recommendations for future Test Bed efforts.

2.0 Summary of Program Tasks

Six major tasks were identified in the contract. The requirements of each of these tasks have been met and the findings are summarized below.

2.1 Task I - Identification of Critical Technologies

For this task, we (FACC) were to use our expertise in the area of power generation and storage to project state-of-the-art technologies at the end of the present decade and to identify critical photovoltaic power generation and power management and distribution technologies, and environmental interaction issues, for the growth space station. In addition, the following requirements were made:

- o Provide rationale and justification for each technology identified and provide a proposed time-phased test plan for the Space Station.
- o Identify specific experiments to be conducted, identify measurements required, and perform limited scaling analysis to establish suitable test bed size before incorporating the experiments into the test plan.

As part of the effort to identify 1990+ technologies, Ford sent out inquiry letters to over forty different companies and government agencies world wide, asking them to identify technologies that they would like to see placed on the test bed and update the current status of those technologies. We received feedback from ten of these requests. These inputs, along with information we obtained as part of the Rocketdyne Space

Station Work Package #4 team, were used to identify experiment requirements, scale the test bed and provide a time phased test plan for the Space Station. Table 1 summarizes the key experiments identified from these inputs. The results of these efforts were presented at the six week review. Summary details of this presentation, along with the inquiry mailing list are provided in Appendix 1. Also included are copies of the responses received.

Table 1

Inputs From Industry Regarding Use
of the Photovoltaic Test Bed

Aerospatiale
- Evaluation of annealing of GaAs cells
- Evaluation of Fresnel and Newton concentration systems (100x)
- Evaluate metal hydrogen battery operation in LEO
- Evaluate albedo affects on gridded back contact (GBC) cells
- Deployment and retraction testing of arrays which cannot be fully tested in 1 G.

United States Air Force
- Testing of Sodium Sulfur batteries

Jet Propulsion Laboratory
- On-orbit testing of lithium batteries

ARCO
- Qualification of tandem junction, amorphous cells

Mitsubishi
- On-orbit real time cell degradation evaluation
- Long term measurements of solar radiation (30 Years)
- On-orbit annealing characteristics of cells
- Evaluation of on-orbit repair techniques for large area solar arrays
- affects of plasma losses on high voltage arrays

Solarex
- Evaluation of long thermal cycling degradation of arrays
- Standard Cell Calibration

Sovonics
- Deployment/retraction testing of amorphous silicon arrays
- Radiation degradation/annealing of amorphous silicon arrays
- Plasma affects on amorphous silicon arrays
- evaluate limits of specific power capability of amorphous
- silicon arrays
- Evaluate the use of ion propulsion with amorphous silicon arrays

2.2 Task II - Determination of Experimental Requirements

The primary requirement of this task was to develop a conceptual design to identify resource requirements from the Space Station. Specific requirements that were addressed are shown summarized below:

- o Provide sketches of the sub-scale test bed in sufficient detail to identify all modular and fixed elements, data acquisition devices and attachments to the Space Station or platform.
- o Provide a functional diagram of changeouts and phases of the test program.
- o Provide a list of all equipment necessary to perform various phases of the experiment.
- o Provide physical characteristics including mass and specific dimensions.
- o Identify requirements including orbit, viewing, power, thermal, data, crew, servicing and contamination sensitivities.
- o Identify diagnostic and other instrumentation required to evaluate the environmental interaction.
- o Provide a representative resource timeline which identify requirements for experiment start-up and assembly, operation, changeout, teardown, and stowage.

Each of the requirements above have been met. Detailed inputs for each of these requirements were presented at the three month review, held at NASA-Lewis on 3 February 1986. Table 2 is a summary of resource requirements for both major and minor experiments which have been identified to date. Table 3 identifies major components of the test bed. Additional summaries inputs relating to each of the above requirements are provided in Appendix 2.

2.3 Task III - Documentation of Experiment Requirements

The major requirement of this task was to provide the Mission Requirements Working Group (MRWG) and Technology Development Advocacy Group (TAG) with requirements of experiments which are planned for test bed integration. These requirements were to be inputted on the appropriate MRWG and TAG data forms. Initial inputs were to be provided at the three month review, with the final inputs provided at the close of the contract.

Table 2

RESOURCE REQUIREMENTS - SENSITIVITIES *

MAJOR EXPERIMENTS	VIEWING	POWER	THERMAL	DATA	CONTAMINATION
1. PV - PLASMA	SOLAR			X	X
2. GROUNDING				X	
3. PV - CONCENTRATOR	SOLAR			X	X
4. ENERGY WHEEL		X		X	
5. THERMOPHOTOVOLTAIC	SOLAR			X	X
6. BATTERY NaS		X	X	X	
7. ANNEALING	SOLAR	X		X	X
8. BATTERIES - Li/TiS		X	X	X	
9. BATTERY Ni/H2		X	X	X	
10. MICROWAVE POWER	SOLAR			X	
11. H2/Br REG FUEL CELL		X	X	X	
MINOR EXPERIMENTS					
1. HIGH VOLTAGE PMAD			X		X
2. ALBEDO - GBC CELLS	SOL/EARTH			X	X
3. DEPLOY/RETRACT				X	
4. PV - AMORPHOUS Si	SOLAR			X	X
5. NEW TECH CELL QUAL	SOLAR			X	X
6. REAL TIME CELL DEG.	SOLAR			X	X
7. ON ORBIT REPAIR					
8. STANDARDS CALIB.	SOLAR			X	X

* EVA AND IVA SUPPORT REQUIRED TO INSTALL AND EXCHANGE EXPERIMENTS ON ABOUT THREE MONTH CENTERS AS SHOWN ON THE TIME-PHASED TEST PLAN.

This task has been completed. As part of the three month review, preliminary TAG and MRWG forms were presented for experiments which had been identified to date. The final copy of these forms, which identify requirements for all key experiments, will be delivered with this report.

Table 3

Major Components of the Test Bed

Mechanical
- Fixed pallet for ESS, PMAD, Thermal and Data
- Sun oriented platform or attachment
- RMS Capability
- Alpha and Beta joints for power/data transfer

Electrical
- Modularity of power converters for ESS management
- Solar array voltage regulation unit
- Power management and distribution units
- Slip rings across Beta joint
- Dissipative loads

Thermal
- Thermal fluid loop on fixed pallet
- Radiator surfaces
- Power supply and controller for resistance heaters
- Thermal blanket attachments
- Thermal instrumentation

Data/Control
- Microprocessor for Data, Test and Control
- DMS interface

Instrumentation
- Langmuir probes
- RF sounder for electron density
- Temperature
- Solar pointing angle
- Exposed and covered calibration cells

2.4 Task IV - Detailed Conceptual Equipment Design

The conceptual design of the test bed was completed in this phase of the study. The requirements associated with this task are summarized below:

- o Provide detailed sketches of equipment components to accomplish experimental objectives.
- o Consider various attachment points for the test bed on the space station and platform options.
- o Identify safety and interface issues.
- o Identify automation and override features.
- o Consider the advantages and disadvantages of having the test bed located on a free flyer, rather than the Space Station.

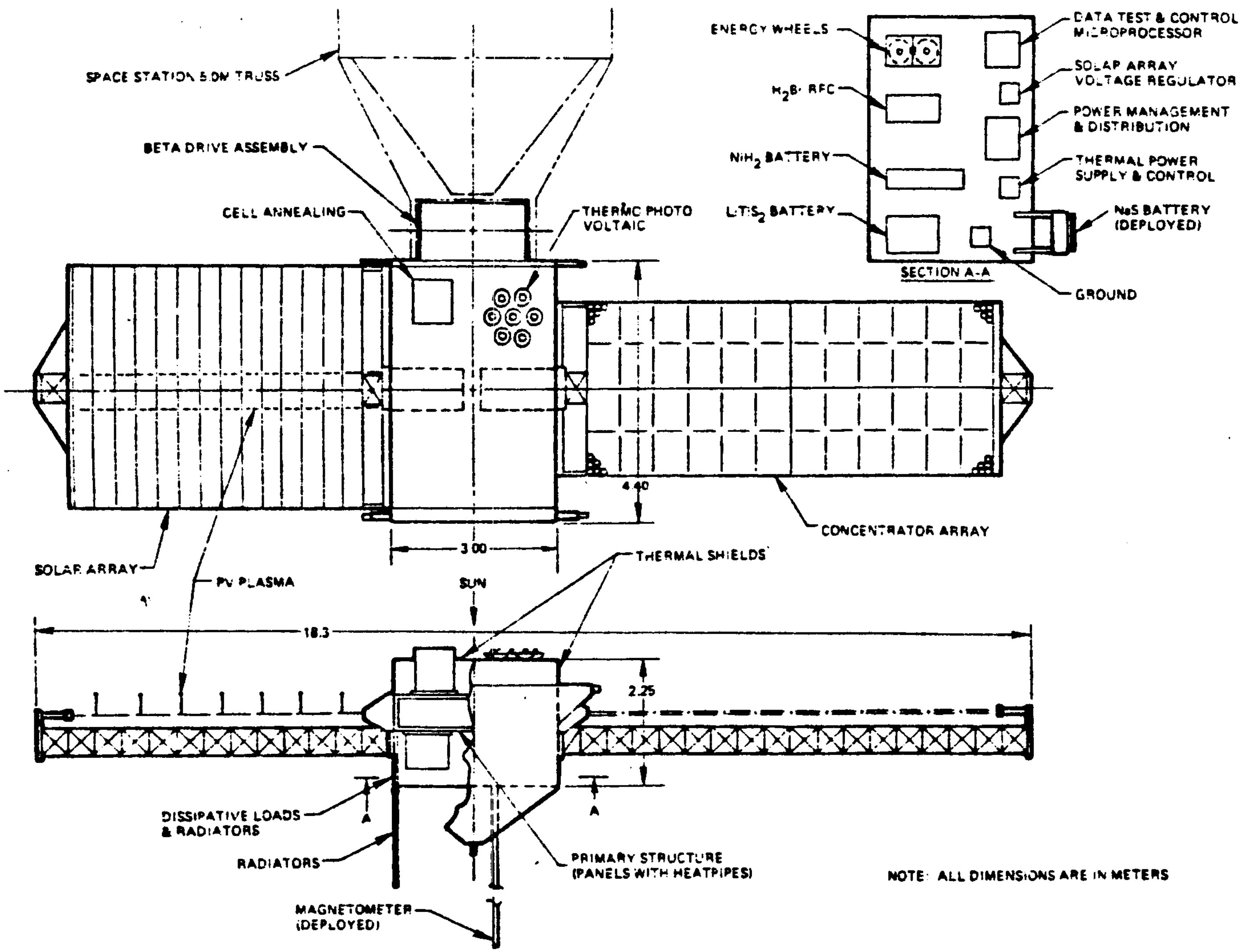
A detailed presentation of the efforts and results of this task was presented at the six month review. Figure 1 shows a baseline deployed test bed configuration. It could be located at a number of different location on the space station, each of which has its own attributes. These are summarized in Table 4. Figure 2 shows how this configuration would be stowed in the shuttle bay for launch. The automation and override features of the test bed were identified and a discussion of the pro's and con's of a free flyer test bed was made. Our recommendations are summarized in Table 5. Safety and interface issues were identified and solutions proposed. Table 6 summarizes the findings and provides recommended courses of action. Further details of each of the major efforts identified above are provided in Appendix 3.

Table 4

TEST BED SITE SELECTION CRITERIA

	SOLAR ILLUMINATION FAVORABLE	NON-INTERFERENCE WITH SPACE STATION OPERATIONS	HIGH COST REAL ESTATE MINIMIZED
LOWER BOOM	SUN UNAVAILABLE	N/A	N/A
END OF S/A BOOM	YES	YES	YES
UPPER BOOM	YES	YES	NO
UPPER KEEL	UNRESOLVED	POSSIBLY	YES
INNER S/A BOOM	UNRESOLVED	POSSIBLY	YES
TWO-PART DESIGN	TBD	POSSIBLY	YES

END OF SOLAR ARRAY BOOM CONFIGURATION DEPLOYED



NOTE: ALL DIMENSIONS ARE IN METERS

APSTB Deployed Configuration

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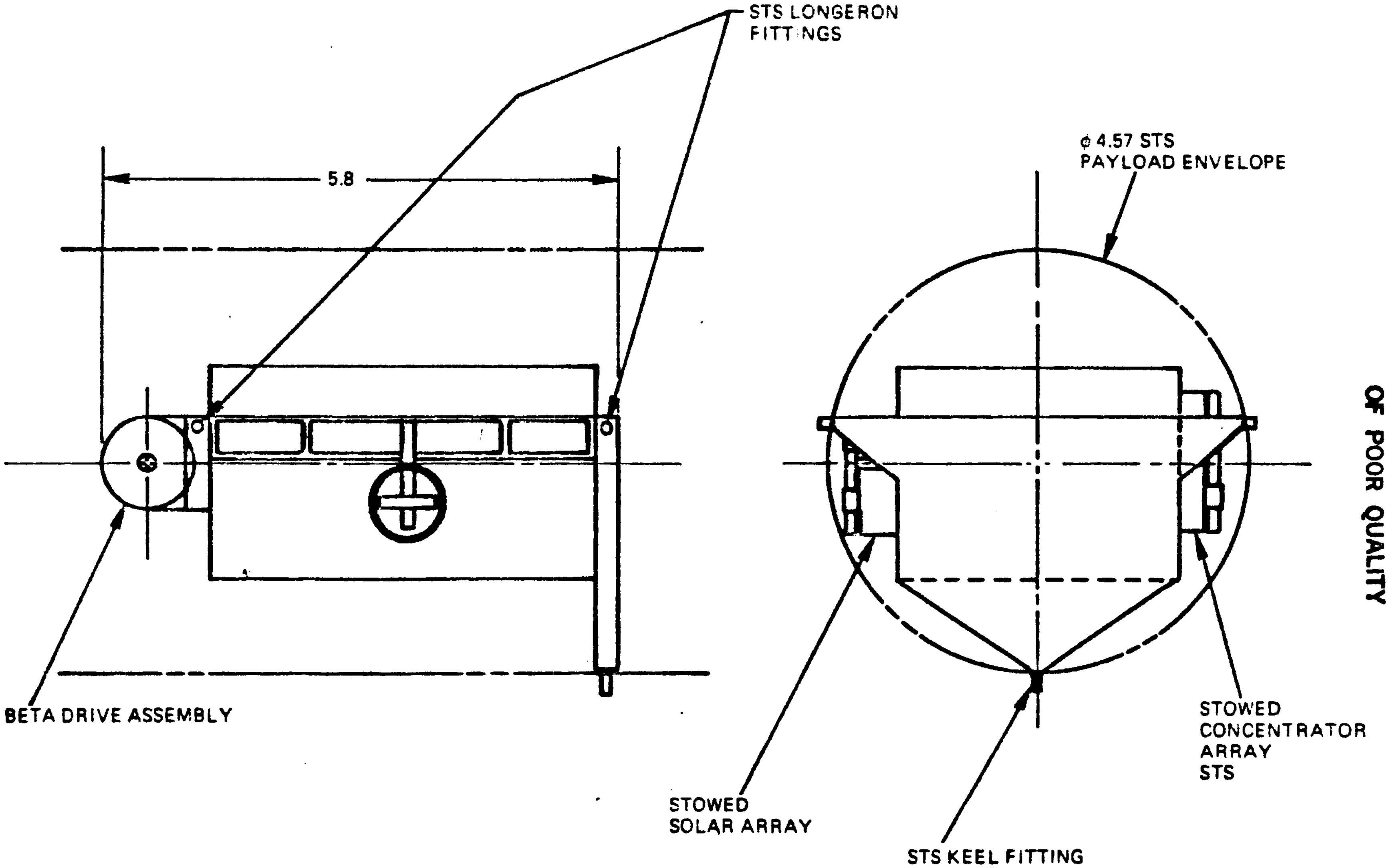
END OF SOLAR ARRAY BOOM

CONFIGURATION STOWED IN SHUTTLE



NOTE: ALL DIMENTIONS IN METERS

APSTB STOWED CONFIGURATION

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Table 5

AUTOMATION AND OVERRIDE FEATURES

- o RELEVANT EXPERIMENT REQUIREMENTS
  - ENERGY STORAGE EXPERIMENTS
    - uP CONTROLLED CHARGE/DISCHARGE CYCLING
    - OVERRIDE WITH BLOCK COMMANDS WHEREVER POSSIBLE
      - START UP
      - TURN OFF
      - INTERRUPT
  - SOLAR EXPERIMENTS
    - OCCASIONALLY MEASURE PERFORMANCE PARAMETERS (I.E. CURRENT-VOLTAGE CHARACTERISTICS)
  - PLASMA EXPERIMENTS
    - AUTOMATIC SEQUENTIAL COMMANDING
- o OPERATIONS REQUIREMENTS
  - COMMANDS BY GROUND OR ASTRONAUT
  - TELEMETRY AVAILABLE TO ASTRONAUTS AND GROUND
  - COMPUTER MONITORIZATION OF CRITICAL PARAMETERS
    - ALARM WHEN LIMITS EXCEEDED
    - AUTOMATIC SAFING OF EXPERIMENTS
  - GROUND OR IVA OPERATIONS HANDBOOK AVAILABLE FOR CONTINGENCY OPERATIONS

2.5 Task V - Preliminary Evolutionary Plan

The major efforts associated with this task included the following:

- o Identify major precursor activities and schedules which would be required of experiments in order to be ready for integration to the test bed.
- o Identify shuttle flights that would be be required to support these activities.
- o Provide a schedule which identifies these activities and tasks by year, from the current state of each technology through integration on the test bed.
- o Provide ROM costs by fiscal year for efforts that would result in the design, test and fabrication of the test bed, through integration on the space station.

Table 6

SAFETY - POTENTIAL HAZARDS

- o TEST BED HAZARDS:
  - HIGH TEMPERATURE RADIATORS
    - DUMMY LOAD RESISTIVE ELEMENTS
    - THERMAL CONTROL FLUID LOOPS
  - HIGH VOLTAGE HARDWARE

- o EXPERIMENT HAZARDS
  - ENERGY STORAGE EXPERIMENTS
    - HIGH TEMPERATURE RADIATORS (e.g. 350 C ON NaS BATTERY EXPERIMENTS)
    - POTENTIALLY EXPLOSIVE EXPERIMENTS (e.g. Li/TiS2 BATTERY AND ENERGY WHEEL)
  - SOLAR ARRAY EXPERIMENTS
    - HIGH VOLTAGE
    - REVERSE-BIASED SOLAR CELLS
    - NOMINALLY HIGH TEMPERATURE COMPONENTS
  - PMAD EXPERIMENTS
    - HIGH VOLTAGES

SAFETY - CATEGORIZATION OF HAZARDS

1. HAZARD RESULTS FROM TOUCH
   - HIGH TEMPERATURE SURFACES
   - HIGH VOLTAGE SURFACES
2. HAZARD OCCURS WHEN ASTRONAUT OBSTRUCTS RADIATOR VIEW OF DEEP SPACE
3. HAZARD OCCURS BY EXPERIMENT EXPLOSION

SAFETY PRECAUTIONS

CONDITIONS 1 OR 2.

- REMOTE LOCATIONS FOR HAZARDOUS HARDWARE
  - CONSCIOUS EFFORT REQUIRED TO ENTER POTENTIALLY HAZARDOUS AREA
  - EVA PRE-OPERATIONS CHECKLIST
  - WARNING LABELS

CONDITION 3.

- PROTECTIVE CONTAINERS TO DIRECT EXPLOSION IN SAFE DIRECTION
- LIMIT SIZE OR ELIMINATE IF SAFETY CANNOT BE ASSURED
- RECONFIGURE EXPERIMENT DURING EVA FOR SAVE OPERATION

All of these tasks were completed. Inputs received from the commercial industry, and from NASA were used to identify major technologies which would most likely use the test bed for research and qualification. The status of each technology was then evaluated and maturity factor assigned. In addition, the experiments were rated as high, medium, or low priority for placement on the test bed. These inputs were then used to schedule necessary activity for each experiment between now and integration onto the test bed. This schedule identified precursor test requirements and shuttle flights necessary to bring the technologies up to a level which would allow them to use the test bed facility. For scheduling purposes, 1994 was used as the first avail50le test bed date. Table 7 summarizes the findings for the high priority experiments. Schedules for the other experiments are included as part of Appendix 4.

In addition to the scheduling tasks, ROM costs by fiscal year were identified for the test bed design, fabrication and test efforts. A four phase design plan, similar to that being used for Space Station, was used in the costing. This plan is presented in Table 8. Overall costs to design, fabricate, test and integrate the test bed were estimated at approximately $32,000,000 (1986 dollars). Detailed summaries of component costs, as well as costs by fiscal year, are shown in Table 9 and Table 10 respectively. Additional inputs relating to this task can be found in Appendix 4.

2.6 Task VI - Scheduling and Reporting

The requirements associated with this task are summarized below:

- Perform a kick-off, six week, three month and six month review at NASA-Lewis.
- Provide monthly status reports to NASA-Lewis, including NASA 533P and 533M financial summary sheets
- Provide initial TAG and MRWG forms at the three month review.
- Provide final TAG and MRWG forms at the end of the contract.

All requirements for scheduling and reporting have been met. Three status update reviews were presented during the program at the NASA-Lewis facility. The final six month review was presented on 5 May 1986.

In addition to the in-person reviews, monthly reports were provided which summarized effort and costs to date. Cost summaries were provided on the NASA forms 533M and 533P as required.

Finally, initial TAG and MRWG forms were provided at the three month review. The final issue of these forms are presented along with this report which completes all reporting requirements.

Table 7.

PRECURSOR TEST PLAN / SCHEDULE
Time Frame (Year)

Experiment	Experiment Priority	Maturity Level	1989	1990	1991	1992	1993	1994 (Test Bed Available)	1995	1996	2000+	
1. Plasma	1	2				C		E				
-Flexible			A	D								
-Concentrator			A	D								
2. High Voltage PMAD	1	2	A	B	D	C		E				
3. Concentrator	1	4		A	B	D	C		E			TOP PRIORITY
4. NaS Battery	1	5			C			E				
5. Advanced NiH2 Bi-Polar Battery	1	3			A	B	D	C		E		
6. Thermo-Photo-voltaic	1	1			A	B	D	C		E		

A - Design and fab EM test item
B - Complete ground testing of EM test item
C - Design and fab Test flight unit
D - Shuttle flight for concept verification
E - Shuttle flight for testbed integration

PRIORITIES
1- Top priority, must be flown
2- Important, will be flown
3- Low priority, space available

Table 8.

OVERALL PHOTOVOLTAIC TEST BED PLAN

TEST BED PHASES	1986	1987	1988	1989	1990	1991	1992	1993	1994
PHASE A									
OVERALL CONCEPTUAL TRADE STUDY	*****								
PHASE B									
COMPONENT DESIGN TRADES	***	********							
PRELIMINARY DESIGN		*****	****						
PHASE C									
ENGINEERING MODEL FAB			****						
ENGINEERING MODEL TEST				***					
QUALIFICATION MODEL FAB				******	**				
QUALIFICATION MODEL TEST					******				
PHASE D									
FINAL DESIGN / CDR						********			
FAB FLIGHT MODEL (Qual Upgrade?)							********		
FINAL TEST							*****	***	
FLIGHT INTEGRATION								*****	
LAUNCH									**

Table 9.

TEST BED COMPONENT COSTS	(1986 DOLLARS)
PMAD	1,250,000
MAGNETOMETER	200,000
TRUSS STRUCTURE	75,000
NI/H2 BATTERIES	500,000
PRIMARY SOLAR ARRAY	2,500,000
ALPHA JOINT	800,000
SUN SENSOR	260,000
BETA JOINT	250,000
MICROPROCESSOR	1,000,000
THERMAL CONTROL	1,500,000
TAPE RECORDER	1,000,000
STRUCTURAL PLATFORMS	2,500,000
LANGMUIR PROBS	1,100,000
TELEMETRY INTERFACES	750,000
CHARGE/DISCHARGE ELECTRONICS	1,265,000
SUBTOTAL	14,950,000
ASSEMBLY & TEST	1,500,000
HIGH RELIABILITY PARTS	300,000
CONFIGURATION ENGINEERING	1,000,000
SYSTEMS ENGINEERING	700,000
MATERIALS ENGINEERING	300,000
SUBTOTAL	18,750,000
G/A (17%)	3.200,000
PROFIT (12%)	2,600,000
TOTAL COSTS	24,550,000

Table 10.

PHOTOVOLTAIC TEST BED ROM COST BY FISCAL YEAR (K$)

PROGRAM PHASE	1987	1988	1989	1990	1991	1992	1993	1994
PHASE B	150	75						
PHASE C		500	5500	6000				
PHASE D					7000	9000	3500	
LAUNCH SUPPORT								1000
TOTAL BY FISCAL YEAR	150	575	5500	6000	7000	9000	3500	1000

TOTAL ESTIMATED COST: $32,725,000

3.0 Other Efforts

Part of the output resulting from the in-person presentations were action items which FACC was asked to address. All of these were addressed and responses provided as part of the monthly reports. In addition, a summary of action item status was presented at the three month and six month reviews. The only action item discussed which was not an original requirement of the contract, was evaluating the possibility of including solar dynamics (SD) as part of the test bed facility. To address this issue, FACC contacted Work Package #4 team members at Rocketdyne to determine the current state of the technology. Sub-scale versions of the Brayton and Sterling SD systems are available in power levels of about one kilowatt. Initial indication is that it would be possible to include SD as part of the baseline test bed configuration. Additional studies on this option will have to be made in the next phase of this study to clearly define constraints and costs.

In addition to the contractual requirements of Section 2.0, Ford was asked to make two additional summary presentations to NASA agencies. On 14 July 1986, a summary of this report was reported to the Technology Development Advocacy Group (TAG), meeting at the Johnson Space Center. A similar presentation was made to NASA headquarters (Code R and Code S), Washington D.C., on 16 October 1986.

4.0 Conclusions and Recommendation

As a result of this study, Ford feels that having a dedicated Photovoltaic Test bed on the Space Station, or on a Free Flyer, is a desirable goal. Inputs from industry indicate their desire for such a test bed which would be available for technology verification and component qualification. Initial sizing and design of the test bed show that a number of different options and locations are possible which would provide the required capabilities. As part of Task V, Ford has provided a development plan, similar to that currently being used for Space Station, which would result in the integration of the Test Bed, onto the Space Station by 1994. The estimated costs for this capability are estimated to be about $ 32 million (1986 dollars). To help amortize these costs, Ford recommends that the test bed be considered as a possible revenue device where industry would pay for its use. This would not only reduce government costs, but provide for faster development and qualification of new technologies. Finally, Ford recommends that a follow-on, 'Phase B' effort be funded. Table 11 summarizes the tasks that should be completed during the Phase B effort.

Table 11.

Recommendations For Future Effort

- The overall test bed plan should follow a pathe similar to that being used for Space Station
- Phase 'B' efforts should be broken into two major tasks:
  - (1) Component Design Trade Studies
    - Identify contractors for major test bed components
    - Perform cost/technical trades on each component
    - Select components to be used on the test bed
  - (2) Preliminary Design
    - Complete design of testbed using components selected in (1) above.
    - Identify top priority experiments and interface with potential users
      - Verify experiment requirements
      - Agree upon responsibilities
      - Identify schedule/cost constraints
    - Customer (NASA) - Test Bed Interface
      - Verify location of test bed on space station
      - Interface with Space Station WP-2 contractor
    - Provide preliminary ICD's for the test bed to be used during Phase 'C' fabrication

APPENDIX 1.

- Request Letter
- Mailing List
- Copy of Responses
- Six Week Review Summary

REQUEST LETTER

Ford Aerospace &
Communications Corporation
Western Development
Laboratories Division

3939 Fabian Way
Palo Alto, California 94303

Phone: (415) 852-5137 or
(415) 852-5131

October 31, 1985
3U5030-REN-798

Dear :

Ford Aerospace and Communications Corporation (FACC) is currently involved in a study, funded by NASA Lewis, to help identify customer test needs for a photovoltaic power test bed which will be attached to the Space Station. The test bed will be designed using a solar array for primary power, an energy storage system and a power management and distribution (PMAD) system all of which will be isolated from the main Space Station power bus.

The objective of this study is to provide a conceptual design for this test bed as well as identify the type of experiments that might use such a facility. These experiments need not be specifically photovoltaic oriented, but may include other subsystems which interface with photovoltaics, such as energy storage systems and power conditioning equipment. By identifying requirements early enough, space station designers can be more responsive to potential users' needs. The targeted time frame for flight is 1992-1995 and the experiments to be conducted should be representative of 1990+ technologies.

As a result, FACC is asking for inputs, from solar cell manufacturers and other companies which interface with photovoltaic systems, that identify the type of experiments and technologies they perceive might use such a test bed, if it were available. The attached questionnaire may be used for inputing suggestions for such experiments and may be included as part of the final report to NASA identifying potential technologies, test bed requirements and test bed users. It would be greatly appreciated if this letter were forwarded to the appropriate personnel who may have inputs for this study.

The schedule for completion of this study is early 1986, so I ask that any ideas or inputs you may have be forwarded to the undersigned no later than 15 December 1985. Let me thank you in advance for your time and effort assisting with ideas for this study. Proper recognition of each contributor will be included as part of the study documentation. If you have any further questions, please feel free to contact me at the address or phone shown on the letterhead.

Sincerely,

FORD AEROSPACE & COMMUNICATION CORP.

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Mitsubishi Electric Corporation
c/o Mr. Carl Yamane
P.O. Box 1650
Palo Alto, CA 94302

Sharp
c/o Mr. Carl Yamane
P.O. Box 1650
Palo Alto, CA 94302

Mr. Dieter Zemmrich
Aerospace Programs Manager
Spectrolab, Inc.
12500 Gladstone Ave.
Sylmar, Calif. 91342

INDUSTRY RESPONSES

Mitsubishi International Corporation

PALO ALTO OFFICE, EMBARCADERO CORPORATE CENTER
2483 EAST BAYSHORE ROAD, SUITE 210, PALO ALTO, CALIFORNIA 94303
TELEPHONE (415) 494-1545
FAX NO. (415) 493-0318
TELEX NO. (RCA) 276-610
HEAD OFFICE: 520 MADISON AVENUE, NEW YORK, NEW YORK 10022

Refer: PLA/MT-263
December 16, 1985

Ford Aerospace & Communications Corp.
WDL Division
3939 Fabian Way
Palo Alto, CA 94303

Attention: Mr. Robert E. Neff, MS-G45
Power & Control Engineering Lab

Subject: Photovoltaic Test Bed for Space Station

Reference: FACC Letter 3U5030-REN-798 of Oct-31-1985

Gentlemen:

We are pleased to enclose herewith Sharp's reply to the reference letter. Sharp has suggested five (5) types of experiments it believes useful for the photovoltaic test bed as seen on the attached questionnaires. We look forward to receiving your comments.

Very truly yours,
MITSUBISHI INTERNATIONAL CORP

Connie Lechnar

Connie Lechnar
Contract Administrator
Aerospace Department
Palo Alto Office

/cl
cc: MC TOK (MT-X)

enclosures

SHARP

SHARP CORPORATION
Electronic Components Group
22-1 HAJIKAMI, SHINJO-CHO, KITAKATSURAGI-GUN,
NARA 639-21, JAPAN

Nara, December 13, 19885

Mr. Robert E. Neff
Ford Aerospace &
Communications Corporation
Western Development
Laboratories Division
Power & Control Engineering Laboratory

Dear Mr. Neff :

Thank you for your letter, and it is our pleasure to propose for your request. Our ideas are presented for your Photovoltaic Power Test Bed which will be expected to fly in 1992-1995. We have 5 ideas for your request as stated on other sheets according to your format.

If you have any interest with our ideas and other solar power systems, or you start to design these experiments on your Photovoltaic Power Test Bed, we will propose to design ideas in detail for your request.

If you have any questions, please feel free to contact us at the address shown on the letterhead.

Sincerely,

SHARP CORPORATION

A. Suzuki

Akio Suzuki
Division General Manager
Photovoltaics Division
Electronic Components Group

PHOTOVOLTAIC POWER TEST BED DATA SHEET

EXPERIMENT TITLE: Evaluation of radiation degradation with various cells

PURPOSE: The objective is to compare and to evaluate the degradation of various solar cells for a long period in the same condition.

PROPOSED FLIGHT DATE (Year) ______

OPERATIONAL DAYS REQUIRED 30 years

APPROXIMATE MASS (Kg) 20

VOLUME:

STOWED: L______ x W______ x H______ = ______ Cu.M.

DEPLOYED: L 1 x W 1 x H 0.2 = 0.2 Cu.M.

REQUIRED ORIENTATION (Inertial, solar, earth, other): Solar

EXTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: 0 Hrs/Day 0 No. of Days

OPERATIONS: 0 Hrs/Day 0 No. of Days

SERVICING: 0 Hrs/Day 0 No. of Days

INTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: 0 Hrs/Day 0 No. of Days

OPERATIONS: 0 Hrs/Day 0 No. of Days

SERVICING: 0 Hrs/Day 0 No. of Days

POWER REQUIREMENTS:

AVERAGE: ______ KW PEAK: ______ KW DC ______ AC ______ HZ______

Hrs/Day: ______ No. of Days: ______

DATA STORAGE: TAPE STORAGE______ IN-SITU TRANSMISSION______ NONE______

DIRECT CONTROL FROM EARTH REQUIRED: YES______ NO______

OTHER REQUIREMENTS:______

ORIGINAL PAGE IS
OF POOR QUALITY

PHOTOVOLTAIC POWER TEST BED DATA SHEET

EXPERIMENT TITLE: High accuracy measurement of solar radiation

PURPOSE: The objective is to measure solar radiation and other radiations(for example, the distribution and intensity of earth's albed) with very high accuracy for a very long term. (for example, 30 years)

PROPOSED FLIGHT DATE (Year) ______

OPERATIONAL DAYS REQUIRED 30 years

APPROXIMATE MASS (Kg) 20

VOLUME:

STOWED: L______ x W______ x H______ = ______ Cu.M.

DEPLOYED: L______ x W______ x H______ = ______ Cu.M.

REQUIRED ORIENTATION (Inertial, solar, earth, other): Solar & Earth

EXTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: 0 Hrs/Day 0 No. of Days

OPERATIONS: 0 Hrs/Day 0 No. of Days

SERVICING: 0 Hrs/Day 0 No. of Days

INTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: 0 Hrs/Day 0 No. of Days

OPERATIONS: 0 Hrs/Day 0 No. of Days

SERVICING: 1 Hrs/Day 60 No. of Days

POWER REQUIREMENTS:

AVERAGE: ______ KW PEAK: ______ KW DC ______ AC ______ HZ______

Hrs/Day: ______ No. of Days: ______

DATA STORAGE: TAPE STORAGE______ IN-SITU TRANSMISSION______ NONE______

DIRECT CONTROL FROM EARTH REQUIRED: YES______ NO______

OTHER REQUIREMENTS: ______

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PHOTOVOLTAIC POWER TEST BED DATA SHEET

EXPERIMENT TITLE: Regeneration test of solar cells by annealing

PURPOSE: The objective is to perform the regeneration test. This expcriment is to certify the technology which regoncrate degradated solar cells by annealing with laser or collected solar heat in space.

PROPOSED FLIGHT DATE (Year) ________

OPERATIONAL DAYS REQUIRED 10

APPROXIMATE MASS (Kg) 30

VOLUME:

STOWED: L 1 x W 1 x H 0.3 = 0.3 Cu.M.

DEPLOYED: L 1 x W 1 x H 1 = 1 Cu.M.

REQUIRED ORIENTATION (Inertial, solar, earth, other): Solar

EXTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: 0 Hrs/Day 0 No. of Days

OPERATIONS: 0 Hrs/Day 0 No. of Days

SERVICING: 0 Hrs/Day 0 No. of Days

INTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: 1 Hrs/Day 1 No. of Days

OPERATIONS: 1 Hrs/Day 2 No. of Days

SERVICING: 2 Hrs/Day 5 No. of Days

POWER REQUIREMENTS:

AVERAGE: ______ KW PEAK: ______ KW DC ____ AC ____ HZ ____

Hrs/Day: ______ No. of Days: ______

DATA STORAGE: TAPE STORAGE ____ IN-SITU TRANSMISSION ____ NONE ____

DIRECT CONTROL FROM EARTH REQUIRED: YES ____ NO ____

OTHER REQUIREMENTS: ________

PHOTOVOLTAIC POWER TEST BED DATA SHEET

EXPERIMENT TITLE: Engineering repair test of Large Solar Array

PURPOSE: The objective is to evaluate the repairing technique. This technique is to find out and exchange the damaged part of solar panels of a Large Solar Array in space.

PROPOSED FLIGHT DATE (Year) ________

OPERATIONAL DAYS REQUIRED 60

APPROXIMATE MASS (Kg) 100

VOLUME:

STOWED: L______ x W______ x H______ = ______ Cu.M.

DEPLOYED: L 30 x W 4 x H 0.5 = 60 Cu.M.

REQUIRED ORIENTATION (Inertial, solar, earth, other): Inertial

EXTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: 4 Hrs/Day 1 No. of Days

OPERATIONS: 4 Hrs/Day 40 No. of Days

SERVICING: 2 Hrs/Day 4 No. of Days

INTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: 4 Hrs/Day 1 No. of Days

OPERATIONS: 4 Hrs/Day 40 No. of Days

SERVICING: 2 Hrs/Day 4 No. of Days

POWER REQUIREMENTS:

AVERAGE: ______ KW PEAK: ______ KW DC ______ AC ______ HZ ______

Hrs/Day: ______ No. of Days: ______

DATA STORAGE: TAPE STORAGE______ IN-SITU TRANSMISSION______ NONE______

DIRECT CONTROL FROM EARTH REQUIRED: YES______ NO______

OTHER REQUIREMENTS: ______

ORIGINAL PAGE IS
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PHOTOVOLTAIC POWER TEST BED DATA SHEET

EXPERIMENT TITLE: Investigation of interactions between a large solar array and space plasma

PURPOSE: The objective is to investigate the interactions between a large solar array with high bus-voltage and space plasma around the array for a long period.

PROPOSED FLIGHT DATE (Year) ________

OPERATIONAL DAYS REQUIRED 90

APPROXIMATE MASS (Kg) 100

VOLUME:

STOWED: L______ x W______ x H______ = ______ Cu.M.

DEPLOYED: L 30 x W 4 x H 0.5 = 60 Cu.M.

REQUIRED ORIENTATION (Inertial, solar, earth, other): Solar

EXTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: 0 Hrs/Day 0 No. of Days

OPERATIONS: 0 Hrs/Day 0 No. of Days

SERVICING: 0 Hrs/Day 0 No. of Days

INTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: 1 Hrs/Day 1 No. of Days

OPERATIONS: 2 Hrs/Day 20 No. of Days

SERVICING: 0 Hrs/Day 0 No. of Days

POWER REQUIREMENTS:

AVERAGE: ______ KW PEAK: ______ KW DC ______ AC ______ HZ ______

Hrs/Day: ______ No. of Days: ______

DATA STORAGE: TAPE STORAGE______ IN-SITU TRANSMISSION______ NONE______

DIRECT CONTROL FROM EARTH REQUIRED: YES______ NO______

OTHER REQUIREMENTS:______

AEROSPACE DIVISION
SOLAREX 201 Perry Parkway, Suite 1 • Gaithersburg, MD 20877 • 301 869-3384

December 12, 1985

Mr. Robert E. Neff, MS-G45
Power and Control Engineering Laboratory
Ford Aerospace and Communications Corp.
3939 Fabian Way
Palo Alto, CA 94303

Dear Mr. Neff:

Enclosed please find responses to your October 31 letter.

Sincerely,

Edward M. Gaddy

Edward M. Gaddy
Manager, Aerospace Products

EMG/bh

Enclosures

PHOTOVOLTAIC POWER TEST BED DATA SHEET

EXPERIMENT TITLE: Solar Cell Calibration Experiment

PURPOSE: To calibrate solar cells to be used as primary standards in setting simulator outputs. A group of cells would be sent to space, protected from radiation by a thick aluminum cover. While pointed at the sun, the cover would be removed and the output of the cells measured. The cells are then recovered and returned to earth. This experiment would be very similar in purpose and structure to

(Cont. on the back)

PROPOSED FLIGHT DATE (Year) Once every other year

OPERATIONAL DAYS REQUIRED 1

APPROXIMATE MASS (Kg) ______

VOLUME:

STOWED: L______ x W______ x H______ = ______ Cu.M.

DEPLOYED: L______ x W______ x H______ = ______ Cu.M.

REQUIRED ORIENTATION (Inertial, solar, earth, other): ______

EXTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: ______ Hrs/Day ______ No. of Days

OPERATIONS: ______ Hrs/Day ______ No. of Days

SERVICING: ______ Hrs/Day ______ No. of Days

INTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: 1 Hrs/Day 1 No. of Days

OPERATIONS: 1 Hrs/Day 1 No. of Days

SERVICING: ______ Hrs/Day ______ No. of Days

POWER REQUIREMENTS:

AVERAGE: ______ KW **PEAK:** ______ KW **DC** ______ **AC** ______ **HZ** ______

Hrs/Day: ______ **No. of Days:** ______

DATA STORAGE: **TAPE STORAGE** ______ **IN-SITU TRANSMISSION** ______ **NONE** ______

DIRECT CONTROL FROM EARTH REQUIRED: **YES** ______ **NO** ______

OTHER REQUIREMENTS: ______

PHOTOVOLTAIC POWER TEST BED DATA SHEET

EXPERIMENT TITLE: Solar Cell Thermal Cycling Experiment

PURPOSE: To test solar panel samples for their ability to withstand thermal cycling. Experiment would place solar panels on the space station for long term cycling. After being in space for years, the panels would be returned to earth for examination to determine effects of the exposure.

PROPOSED FLIGHT DATE (Year) ASAP

OPERATIONAL DAYS REQUIRED None

APPROXIMATE MASS (Kg) 3

VOLUME:

STOWED: L 1m x W 1m x H .02 = .02 Cu.M.

DEPLOYED: L ____ x W ____ x H ____ = ____ Cu.M.

REQUIRED ORIENTATION (Inertial, solar, earth, other): Ideally panel should face sun during sunlit period of the orbit.

EXTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: 1 **Hrs/Day** 5 **No. of Days** per year.

OPERATIONS: 1 **Hrs/Day** 5 **No. of Days** per year.

SERVICING: ____ **Hrs/Day** ____ **No. of Days**

INTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: ____ **Hrs/Day** ____ **No. of Days**

OPERATIONS: ____ **Hrs/Day** ____ **No. of Days**

SERVICING: ____ **Hrs/Day** ____ **No. of Days**

POWER REQUIREMENTS:

AVERAGE: None **KW** **PEAK:** ____ **KW** **DC** ____ **AC** ____ **HZ** ____

Hrs/Day: ____ **No. of Days:** ____

DATA STORAGE: **TAPE STORAGE** None **IN-SITU TRANSMISSION** ____ **NONE** ____

DIRECT CONTROL FROM EARTH REQUIRED: **YES** ____ **NO** ____

OTHER REQUIREMENTS: ____

DEPARTMENT OF THE AIR FORCE
AIR FORCE WRIGHT AERONAUTICAL LABORATORIES (AFSC)
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

REPLY TO
ATTN OF: AFWAL/POOS-2 (Don Warnock, (513) 255-6241)

17 December 1985

SUBJECT: Power System Experimentation Unit - Sodium-Sulfur Battery

TO: Ford Aerospace & Communications Corp.
Western Development Laboratories Division
Attn: Daniel L. Hutchins, MS-G45
3939 Fabian Way
Palo Alto, CA 94303

We would like to propose a sodium-sulfur battery experiment for consideration in your conceptual study of a power system experimentation unit as described in your letter of 26 November. Lt Ross Dueber of our group has filled out your questionaire to the extent of our present knowledge. If you have any further questions please contact Lt Dueber at the same address or at telephone (513) 255-6241.

DON R. WARNOCK
Power Technology Branch
Aerospace Power Division
Aero Propulsion Laboratory

1 Atch
PV Power Test Bed Data Sheet

cc: AFWAL/POOS-2 (Lt Dueber)

PHOTOVOLTAIC POWER TEST BED DATA SHEET

EXPERIMENT TITLE: Sodium-Sulfur Battery Flight Test

PURPOSE: To demonstrate the operability of a rechargeable Sodium-sulfur battery in space environment.

PROPOSED FLIGHT DATE (Year) 1991-92

OPERATIONAL DAYS REQUIRED 180 days

APPROXIMATE MASS (Kg) 20 Kg

DIMENSIONS:

STOWED: L 43cm x W 43cm x H 32cm

DEPLOYED: L " x W " x H "

OTHER DIMENSIONAL CHARACTERISTICS: ______

REQUIRED ORIENTATION (Inertial, solar, earth, other): ______

POINTING ACCURACY REQUIRED: N/A

EXTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: ______ Hrs/Day ______ No. of Days

OPERATIONS: ______ Hrs/Day ______ No. of Days

SERVICING: ______ Hrs/Day ______ No. of Days

INTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: ______ Hrs/Day ______ No. of Days

OPERATIONS: ______ Hrs/Day ______ No. of Days

SERVICING: ______ Hrs/Day ______ No. of Days

THERMAL REQUIREMENTS: TYPE: OPEN ______ CLOSED ✓

OPERATING TEMPERATURE: 350 °C

HEAT DUTY a) ______ watts
b) ______ watts

OTHER ______

POWER REQUIREMENTS:

AVERAGE: 1.00 KW PEAK: N/A KW DC ✓

QUALITY: ______ AC ______ HZ ______

Hrs/Day: ______ No. of Days: ______

DATA STORAGE: TAPE STORAGE ✓ IN-SITU TRANSMISSION ______ NONE ______

DIRECT CONTROL FROM EARTH REQUIRED: YES ______ NO ______

RETRIEVEABILITY DESIRED: YES ✓ NO ______

OTHER REQUIREMENTS: ______

Société Nationale Industrielle
aerospatiale
Division Systèmes Balistiques et Spatiaux
Etablissement de Cannes

100, Boulevard du Midi - BP 99 - 06322 Cannes La Bocca Cedex - Téléphone : (93) 93.90.00 - Télex : AECAN 470 902F
Télégramme : Aérospatiale Cannes - CCP Marseille 1201-93J - SIRET 572 094 514 - 00401 - APE 3304 - B 572094514 - RC CANNES

M. Robert E. Neff
FACC
Western Development
Laboratories Division
3939 Fabian Way
Palo Alto, California 94303

Your letter 3U5030-REN-798
V./Réf. dated october 31, 1985

N./Réf.

V./Correspondant : A316 CA/CG

Tél.

Le December 20th, 1985

Dear Bob,

In reply to your reference letter relative to a photovoltaic power test bed attached to the Space Station, I am enclosing herewith some suggestions which might be of some use in your prospective study.

For any further detail or clarification, please contact Lionel Pelenc, Tel 93.93.90.24 at our Cannes' establishment.

Sincerely yours

M.A ZILIANI

Solar Array Department Manager

PHOTOVOLTAIC POWER TEST BED DATA SHEET

EXPERIMENT TITLE: Gallium Arsenide Cells Aunealing

PURPOSE: Evaluate the possible annealing of Ga As cells with in orbit radiation fluence and under different temperature.

PROPOSED FLIGHT DATE (Year) 1992 +

OPERATIONAL DAYS REQUIRED 200

APPROXIMATE MASS (Kg) 3

VOLUME:

STOWED: L 0.5 x W 0.5 x H 0.5 = 0.125 Cu.M.

DEPLOYED: L " x W " x H " = " Cu.M.

REQUIRED ORIENTATION (Inertial, solar, earth, other): Solar

EXTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: 1 Hrs/Day 1 No. of Days

OPERATIONS: 0 Hrs/Day 0 No. of Days

SERVICING: 0 Hrs/Day 0 No. of Days

INTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: 1 Hrs/Day 1 No. of Days

OPERATIONS: 1 Hrs/Day 200 No. of Days

SERVICING: 0 Hrs/Day 0 No. of Days

POWER REQUIREMENTS:

AVERAGE: 1 KW PEAK: 2 KW DC 30 V AC ___ HZ ___

Hrs/Day: 24 No. of Days: 200

DATA STORAGE: TAPE STORAGE ___ IN-SITU TRANSMISSION ___ NONE ___

DIRECT CONTROL FROM EARTH REQUIRED: YES ___ NO ___

OTHER REQUIREMENTS: ___

PHOTOVOLTAIC POWER TEST BED DATA SHEET

EXPERIMENT TITLE: MICRO CONCENTRATION

PURPOSE: Evaluate degradation of micro concentration system in orbit, to correlate ground test

Micro concentrators will be cassegranian, Fresnel lens and Newton with 100 concentration factor

PROPOSED FLIGHT DATE (Year) 1992 +

OPERATIONAL DAYS REQUIRED 30

APPROXIMATE MASS (Kg) 10

VOLUME:

STOWED: L 0.5 x W 0.5 x H 0.3 = 0.075 Cu.M.

DEPLOYED: L ____ x W ____ x H ____ = ____ Cu.M.

REQUIRED ORIENTATION (Inertial, solar, earth, other): Solar

EXTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: 1 Hrs/Day 1 No. of Days

OPERATIONS: 0 Hrs/Day 0 No. of Days

SERVICING: 0 Hrs/Day 0 No. of Days

INTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: 1 Hrs/Day 1 No. of Days

OPERATIONS: 1 Hrs/Day 30 No. of Days

SERVICING: 0 Hrs/Day 0 No. of Days

POWER REQUIREMENTS:

AVERAGE: 0.1 KW PEAK: 0.2 KW DC 30 V

AC ____ HZ ____

Hrs/Day: 24 No. of Days: 30

DATA STORAGE: TAPE STORAGE X IN-SITU TRANSMISSION X NONE ____

DIRECT CONTROL FROM EARTH REQUIRED: YES ____ NO x

OTHER REQUIREMENTS: ____

PHOTOVOLTAIC POWER TEST BED DATA SHEET

EXPERIMENT TITLE: METAL HYDROGEN BATTERY BEHAVIOUR

PURPOSE: The purpose of this experiment is to evaluate the behaviour of a metal hydrogen battery on low orbit This battery would consist typically in 2 pressurized nickel-hydrogen cells and an associated control init.

PROPOSED FLIGHT DATE (Year) 1992

OPERATIONAL DAYS REQUIRED Throughout the flight (lifetime behaviour)

APPROXIMATE MASS (Kg) 4.5

VOLUME:

STOWED: L 0.2 x W 0.2 x H 0.2 = 8×10^{-3} Cu.M.

DEPLOYED: L d° x W d° x H d° = d° Cu.M.

REQUIRED ORIENTATION (Inertial, solar, earth, other): Baseplate toward North

EXTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: 1 Hrs/Day 1 No. of Days

OPERATIONS: / Hrs/Day / No. of Days

SERVICING: / Hrs/Day / No. of Days

INTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: / Hrs/Day / No. of Days

OPERATIONS: / Hrs/Day / No. of Days

SERVICING: / Hrs/Day / No. of Days

POWER REQUIREMENTS:

AVERAGE: 0.035 KW PEAK: 0.050 KW DC 20A
AC ____ HZ ____

Hrs/Day: 16 No. of Days: All

DATA STORAGE: TAPE STORAGE X IN-SITU TRANSMISSION ____ NONE ____

DIRECT CONTROL FROM EARTH REQUIRED: YES ____ NO X

OTHER REQUIREMENTS: TM/TC = 10

PHOTOVOLTAIC POWER TEST BED DATA SHEET

EXPERIMENT TITLE: INTEGRATED BIFACIAL CELLS

PURPOSE: Measure power increase due to Earth albedo on rear side and its consequences at power control level.

PROPOSED FLIGHT DATE (Year) 1992

OPERATIONAL DAYS REQUIRED 30

APPROXIMATE MASS (Kg) 1

VOLUME:

STOWED: L 0,3 x W 0,3 x H 0,2 = 0,018 Cu.M.

DEPLOYED: L " x W " x H " = " Cu.M.

REQUIRED ORIENTATION (Inertial, solar, earth, other): Solar / earth

EXTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: 1 Hrs/Day 1 No. of Days

OPERATIONS: 0 Hrs/Day 0 No. of Days

SERVICING: 0 Hrs/Day 0 No. of Days

INTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: 1 Hrs/Day 1 No. of Days

OPERATIONS: 1 Hrs/Day 30 No. of Days

SERVICING: 0 Hrs/Day 0 No. of Days

POWER REQUIREMENTS:

AVERAGE: 0,1 KW PEAK: 0,2 KW DC 30 V

AC ____ HZ ____

Hrs/Day: 24 No. of Days: 30

DATA STORAGE: TAPE STORAGE X IN-SITU TRANSMISSION ____ NONE ____

DIRECT CONTROL FROM EARTH REQUIRED: YES ____ NO X

OTHER REQUIREMENTS: ____

PHOTOVOLTAIC POWER TEST BED DATA SHEET

EXPERIMENT TITLE: DEPLOYMENT / RETRACTION SYSTEM

PURPOSE: 1) 0g testing of deplouable equipement not flexible on ground
2) life duration testing invacuum and 0g conditions of moters

PROPOSED FLIGHT DATE (Year) 1992 +

OPERATIONAL DAYS REQUIRED 90

APPROXIMATE MASS (Kg) 15

VOLUME:

STOWED: L 0.8 x W 0.5 x H 0.3 = 0.12 Cu.M.

DEPLOYED: L 0.8 x W 2.0 x H 0.1 = 0.16 Cu.M.

REQUIRED ORIENTATION (Inertial, solar, earth, other): Solar

EXTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: 1 Hrs/Day 1 No. of Days

OPERATIONS: 0 Hrs/Day 0 No. of Days

SERVICING: 1 Hrs/Day 10 No. of Days

INTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: 1 Hrs/Day 1 No. of Days

OPERATIONS: 1 Hrs/Day 90 No. of Days

SERVICING: 0 Hrs/Day 0 No. of Days

POWER REQUIREMENTS:

AVERAGE: 0.1 KW PEAK: 0.2 KW DC 30 V
AC ______ HZ ______

Hrs/Day: 3 No. of Days: 90

DATA STORAGE: TAPE STORAGE X IN-SITU TRANSMISSION X NONE ______

DIRECT CONTROL FROM EARTH REQUIRED: YES X NO ______

OTHER REQUIREMENTS: ______

ARCO Solar, Inc.
9351 Deering Avenue
Mailing Address: Box 2105
Chatsworth, California 91313
Telephone 818 700 7000
Telex 674838
TWX 910 494 2791

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December 05, 1985

Robert E. Neff
Ford Aerospace & Communication Corp.
Western Development
Laboratories Division
3939 Fabian Way
Palo Alto, Calif. 94303

Dear Mr. Neff:

Attached is our preliminary response to your questionnaire regarding the proposed photovoltaic test bed for space station experimentation. We would like to be kept informed of progress on the project so that we can further refine our plans and expectations.

Yours very truly,

Don Morel

Don L. Morel
Director of Research

Entered by Neff

Misc	FACC/WDL CORRESPONDENCE MESSAGE CENTER	
021790	R.E. Neff G45		

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PHOTOVOLTAIC POWER TEST BED DATA SHEET

EXPERIMENT TITLE: TANDEM THIN FILM PHOTOVOLTAIC MODULE

PURPOSE: SPACE QUALIFICATION

PROPOSED FLIGHT DATE (Year) 1992

OPERATIONAL DAYS REQUIRED 2

APPROXIMATE MASS (Kg) 4

VOLUME:

STOWED: L 1.3 x W .61 x H .25 = .20 Cu.M.

DEPLOYED: L 1.3 x W .61 x H .25 = .20 Cu.M.

REQUIRED ORIENTATION (Inertial, solar, earth, other): SOLAR

EXTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: 1 Hrs/Day 1 No. of Days

OPERATIONS: 0 Hrs/Day ______ No. of Days

SERVICING: 0 Hrs/Day ______ No. of Days

INTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: 1 Hrs/Day 1 No. of Days

OPERATIONS: 0 Hrs/Day ______ No. of Days

SERVICING: 0 Hrs/Day ______ No. of Days

POWER REQUIREMENTS:

AVERAGE: 0 KW PEAK: 0 KW DC ______ AC ______ HZ ______

Hrs/Day: ______ No. of Days: ______

DATA STORAGE: TAPE STORAGE ✓ IN-SITU TRANSMISSION ______ NONE ______

DIRECT CONTROL FROM EARTH REQUIRED: YES ______ NO ✓

OTHER REQUIREMENTS: POWER RECORDING APPARATUS

Main Office
6180 Cochran Road
P.O. Box 39608
Solon, Ohio 44139
216-349-2827
Telex: 6711235

Deposition Plant
1100 West Maple Road
Troy, Michigan 48084
313-362-4170

A partnership of
The Standard Oil Company (Ohio)
and Energy Conversion Devices, Inc.

SOVONICS™
SolarSystems

December 4, 1985

Mr. Robert E. Neff MS-G45
Power & Control Engineering Laboratory
Ford Aerospace & Communications Corporation
Western Development
Laboratories Division
3939 Fabian Way
Palo Alto, California 94303

Dear Mr. Neff:

Thank you for your letter of October 31 in which you invited Energy Conversion Devices, Inc. (ECD) to propose tests for the Space Station. As you know ECD is engaged in the development of amorphous silicon alloy solar cells and modules through Sovonics Solar Systems, a partnership between ECD and the Standard Oil Company (SOHIO).

At Sovonics, during the past two years, we have developed the Ultralight™ photovoltaic modules which may be suitable for applications in space. A detailed description of the structure and performance of these modules is included in two papers which I presented in the 18th IEEE Photovoltaic Specialists Conference in Las Vegas, October 21-25, of this year.

The tests that we propose involve such ultralight arrays. Together five ~~four~~ tests are listed, involving three different arrays, each of which would have an output of about 1250 at AMO.

I should point out that we would be prepared to start such tests as early as 1987, so that our arrays would be in use rather than in tests on the Space Station. Please convey the message to NASA.

I look forward to collaboration with you in the near future.

Sincerely yours,

J J Hanak

J. J. Hanak

JJH/sz

Enclosures (4)

From: J. J. Hanak
Sovonics Solar Systems

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PHOTOVOLTAIC POWER TEST BED DATA SHEET

I. EXPERIMENT TITLE: DEPLOYMENT AND RETRACTION OF A ROLL-UP AMORPHOUS SILICON PV ARRAY*

PURPOSE: (1) Feasibility of repeated deployment and retraction of a flexible roll-up PV array in and out of its cannister and its effect on array performance.

(2) Stiffness and vibration testing

(3) Temperature cycling.

PROPOSED FLIGHT DATE (Year) 1992 or earlier

OPERATIONAL DAYS REQUIRED 30 to 90 days (See test II).

APPROXIMATE MASS (Kg) 50

VOLUME:

	L	W	H	=	Cu.M.
STOWED:	2.7	0.30	0.15	0.12	PV Array
	0.5	0.5	0.3	0.075	Test Equipment
DEPLOYED:	2.7	4.2	0.05	0.57	PV Array
	0.5	0.5	0.3	0.075	Test Equipment

REQUIRED ORIENTATION (Inertial, solar, earth, other): Solar

EXTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: 0.5 Hrs/Day 1 No. of Days

OPERATIONS: 0 Hrs/Day 0 No. of Days - Operation can be automated; number of tests is optional.

SERVICING: 0 Hrs/Day 0 No. of Days

INTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: 0.5 Hrs/Day 1 No. of Days

OPERATIONS: 0.1 Hrs/Day 30-90 No. of Days - Monitoring automated experiment.

SERVICING: - Hrs/Day - No. of Days - As needed

POWER REQUIREMENTS:

AVERAGE: 0.5 KW PEAK: 0.7 KW DC ___ AC X HZ 60

Hrs/Day: 24 No. of Days: 30-90

DATA STORAGE: TAPE STORAGE X IN-SITU TRANSMISSION X NONE ___

DIRECT CONTROL FROM EARTH REQUIRED: YES ___ NO X

OTHER REQUIREMENTS: NONE

* See references on reverse side.

From: J. J. Hanak
Sovonics Solar Systems

PHOTOVOLTAIC POWER TEST BED DATA SHEET

II EXPERIMENT TITLE: EFFECT OF LIGHT AND SPACE RADIATION ON THE PV PERFORMANCE OF ROLL-UP ARRAYS

PURPOSE: (The same experimental setup as in experiment I) amorphous silicon alloy PV cells after exposure to light, electron and proton radiation degrade somewhat in their PV performance, however, the performance can be restored upon 0.5-3 hour annealing at 150-200°C. In this experiment the array would be periodically retracted into its cannister and there annealed by solar heat to restore its performance.

PROPOSED FLIGHT DATE (Year) 1992 or earlier

OPERATIONAL DAYS REQUIRED 90

APPROXIMATE MASS (Kg) 50

VOLUME:

	L		W		H				
STOWED:	2.7	x	0.30	x	0.15	=	0.122	Cu.M.	PV ARRAY
	0.5		0.5		0.3		0.075		TEST EQUIP.
DEPLOYED:	2.7	x	4.2	x	0.05	=	0.57	Cu.M.	PV ARRAY
	0.5		0.5		0.3		0.075		TEST EQUIP.

REQUIRED ORIENTATION (Inertial, solar, earth, other): ______

EXTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: 0.5 Hrs/Day 1 No. of Days

OPERATIONS: 0 Hrs/Day 0 No. of Days

SERVICING: 0 Hrs/Day 0 No. of Days

INTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: 0.5 Hrs/Day 1 No. of Days

OPERATIONS: 0.1 Hrs/Day 10 No. of Days

SERVICING: - Hrs/Day - No. of Days AS NEEDED

POWER REQUIREMENTS:

AVERAGE: 0.5 KW PEAK: 0.7 KW DC ______ AC x HZ 60

Hrs/Day: 24 No. of Days: 30-90

DATA STORAGE: TAPE STORAGE x IN-SITU TRANSMISSION x NONE ______

DIRECT CONTROL FROM EARTH REQUIRED: YES ______ NO ______

OTHER REQUIREMENTS: Helium or Argon gas, as a heat exchanger, would be desirable during the annealing experiments, approximately 200 liters total (at standard temperature and pressure).

From: J. J. Hanak
Sovonics Solar Systems

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PHOTOVOLTAIC POWER TEST BED DATA SHEET

III EXPERIMENT TITLE: HIGH VOLTAGE SOLAR ARRAY PLASMA PROTECTION TECHNIQUE*

PURPOSE: Amorphous solicon alloy PV arrays are highly suitable for high voltage construction and operation. Because of their monolithic structure the arrays are totally encapsulated in a flexible laminate. Because of this, protection against space plasma effects and high voltage opeation are feasible. In particular, solution proposed by Dunbar ET AL can be easily incorporated. We propose deploying a continuous 1000 volt series-connected roll-up array 10x1 M in size, with taps at desired voltage intervals Array voltage will be proportional to length deployed.

PROPOSED FLIGHT DATE (Year) 1992 or earlier

OPERATIONAL DAYS REQUIRED 10 testing
90 total

APPROXIMATE MASS (Kg) 40

VOLUME:

	L		W		H			
STOWED:	1.2	x	0.40	x	0.20	=	0.10	Cu.M. PV ARRAY
	0.5		0.5		0.3		0.075	
DEPLOYED:	10.3	x	1.1	x	0.05	=	0.57	Cu.M.

REQUIRED ORIENTATION (Inertial, solar, earth, other): SOLAR

EXTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: 0.5 Hrs/Day 1 No. of Days

OPERATIONS: 0 Hrs/Day 0 No. of Days

Extra-vehicular mechanical motion can be controlled intra vehicularly.

SERVICING: ___ Hrs/Day ___ No. of Days Not anticipated.

INTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: 0.5 Hrs/Day 1 No. of Days

OPERATIONS: 2 Hrs/Day 10 No. of Days

SERVICING: ___ Hrs/Day ___ No. of Days As Needed

POWER REQUIREMENTS:

AVERAGE: 0.5 KW PEAK: 0.7 KW DC ___ AC x HZ ___

Hrs/Day: 24 No. of Days: 90 (life testing at progressively higher voltage.)

DATA STORAGE: TAPE STORAGE x IN-SITU TRANSMISSION x NONE ___

DIRECT CONTROL FROM EARTH REQUIRED: YES ___ NO ___

OTHER REQUIREMENTS: NONE

* See references on reverse side.

From: J. J. Hanak
Sovonics Solar Systems

ORIGINAL PAGE IS OF POOR QUALITY

PHOTOVOLTAIC POWER TEST BED DATA SHEET

IV. EXPERIMENT TITLE: LIMIT OF SPECIFIC POWER OF ULTRALIGHT AMORPHOUS SILICON PV ARRAYS

PURPOSE: Amorphous silicon alloy PV modules have already reached specific power of 2,400 $\bar{w}$/kg at AM1 (Ref. 1) and 5,000 $\bar{w}$/kg is expected. We propose to construct a series of arrays having progressively lower mass and module thickness, to determine the maximum practical array specific power. The results of these tests have important implications for interplanetary spacecraft, ion-propelled spacecraft and for fuel consumption of LEO spacecraft.

PROPOSED FLIGHT DATE (Year) 1992 or earlier

OPERATIONAL DAYS REQUIRED 90

APPROXIMATE MASS (Kg) 50

VOLUME:

	L		W		H			Cu.M.	
STOWED:	2.7 / 0.5	x	0.30 / 0.5	x	0.15 / 0.3	=	0.122 / 0.075	Cu.M.	Array / Test Equipment
DEPLOYED:	2.7 / 0.5	x	4.2 / 0.5	x	0.05 / 0.3	=	0.57 / 0.075	Cu.M.	Array / Test Equipment

REQUIRED ORIENTATION (Inertial, solar, earth, other): Solar

EXTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: 2.0 Hrs/Day 1 No. of Days

OPERATIONS: 0 Hrs/Day 0 No. of Days

SERVICING: ______ Hrs/Day ______ No. of Days

INTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: 0.5 Hrs/Day 1 No. of Days

OPERATIONS: 0.1 Hrs/Day 10 No. of Days - Over 90 days

SERVICING: ______ Hrs/Day ______ No. of Days

POWER REQUIREMENTS:

AVERAGE: 0.5 KW PEAK: 0.7 KW DC ______ AC X HZ 60

Hrs/Day: 24 No. of Days: 90

DATA STORAGE: TAPE STORAGE______ IN-SITU TRANSMISSION______ NONE______

DIRECT CONTROL FROM EARTH REQUIRED: YES______ NO______

OTHER REQUIREMENTS: ______

PHOTOVOLTAIC POWER TEST BED DATA SHEET

EXPERIMENT TITLE: ION PROPULSION POWERED BY AMORPHOUS SILICON PV ARRAY

PURPOSE: BECAUSE OF VERY HIGH SPECIFIC POWER, a-Si ULTRALIGHT ARRAYS WOULD BE IDEAL FOR INTERPLANETARY SPACECRAFT PROPELLED BY ION THRUSTERS. A STATIC TEST OF ARBITRARY SIZE IS PROPOSED FIRST ON THE SPACE STATION TO TEST THIS CONCEPT. LATER A TEST OF SPACECRAFT LAUNCHED FROM THE SPACE STATION IS PROPOSED.

PROPOSED FLIGHT DATE (Year) 1992-1995

OPERATIONAL DAYS REQUIRED ______

APPROXIMATE MASS (Kg) ______

VOLUME:

STOWED: L______ x W______ x H______ = ______ Cu.M.

DEPLOYED: L______ x W______ x H______ = ______ Cu.M.

REQUIRED ORIENTATION (Inertial, solar, earth, other): ______

EXTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: ______Hrs/Day ______ No. of Days

OPERATIONS: ______Hrs/Day ______ No. of Days

SERVICING: ______Hrs/Day ______ No. of Days

INTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: ______Hrs/Day ______ No. of Days

OPERATIONS: ______Hrs/Day ______ No. of Days

SERVICING: ______Hrs/Day ______No. of Days

POWER REQUIREMENTS:

AVERAGE: ______KW PEAK: ______KW DC ______ AC ______ HZ______

Hrs/Day: ______ No. of Days: ______

DATA STORAGE: TAPE STORAGE______ IN-SITU TRANSMISSION______ NONE______

DIRECT CONTROL FROM EARTH REQUIRED: YES______ NO______

OTHER REQUIREMENTS: ______

Jet Propulsion Laboratory
California Institute of Technology
4800 Oak Grove Drive
Pasadena, California 91109
(818) 354-4321

JPL

November 25, 1985

Refer to: 342-EC:ns

Mr. Robert E. Neff MS-G45
Power and Control Engineering Laboratory
Ford Aerospace and Communication Corp.
3939 Fabian Way
Palo Alto, CA 94303

RE: Letter to John Scott-Monck, dated October 31, 1985 345050-REN-798

Dear Mr. Neff:

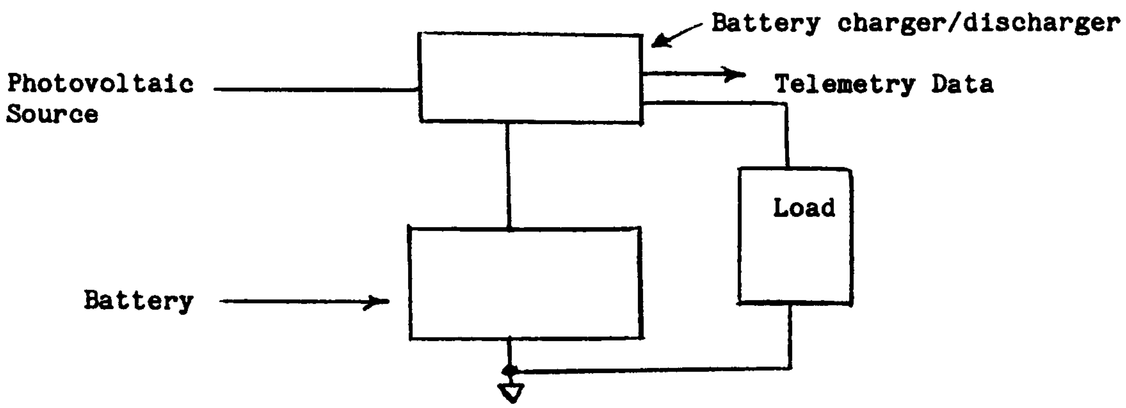
In response to your referenced letter, JPL Section 342, the Electric Power Systems Section, would be pleased to propose an experiment for a space station photovoltaic power test bed if it existed. The title of the experiment we would like to undertake is "Rechargeable Lithium Battery Power System."

As a background, JPL, as the NASA Lead Center for lithium high energy cell technology, has been working over the past five years to develop lithium-base cell/batteries, both primary and secondary. The program has advanced to the point where test specimens have shown promise of becoming safe, reliable, high energy, primary and secondary power sources. The specific program objectives for the primary and secondary power sources are as follows:

<u>OBJECTIVE</u>	<u>GOAL</u>	<u>APPLICATIONS</u>
<u>$Li\text{-}SOCl_2$ PRIMARY</u>		
Increase Specific Energy	300 WH/Kg	o Probes, Penetrators
High Rate Capability	2 H	o Vehicles
Increase Storage Life	5 Years	o Free Flyers/Short Term
Cylindrical/Prismatic Cells	10-500 AH	o Maneuvering Equip } Space Station o Crew Equipment
<u>$Li\text{-}TiS_2$ SECONDARY</u>		
Increase Specific Energy	100 WH/Kg	o Planetary
Demonstrate Cycle Life	10000 Cycles	o Comet Rendezvous
Extend Life	10 Years	o Rovers o Planetary Stations

Since the lithium-base battery technology is presently in the research/development stage and is expected to mature with experimental flight-worthy cells/batteries early in the 1990's, the proposed experiment should meet the requirements for the test bed program planning.

The proposed experiment will require the photovoltaic source in order to evaluate tne performance of the secondary battery as a viable rechargeable power source under the actual zero g gravity environment. The power from the photovoltaic source will be used to charge the battery during sunlight periods and the battery will be discharged to load during the sun occultation periods. The experiment will contain the secondary battery, the associated electronics for discharging and charging the battery, the load, and telemetry measurements of battery voltage, current and temperature. The objective of the experiment is to evaluate the performance and life electrochemical parameters of this high energy secondary lithium base battery and the required electronics to support its performance as a power source (charging and discharging cycles) at the actual space operating conditions (PV source, 0 g gravity). The block diagram of the experiment is shown below.



JPL will be planning to fabricate, test and deliver a flight worthy experiment to meet the requirements and schedules of the PV power test bed program. The data supplied to the attached questionnaire should be considered preliminary. If you have any further questions, please feel free to contact me at the address or phone shown.

Sincerely,

E. N. Costogue, Member of Technical Staff
Space Power Section
(818) 354-3922
Mail Stop 198-220

cc: W. Bachman
R. Key
H. Stadler
R. Stephenson

PHOTOVOLTAIC POWER TEST BED DATA SHEET

EXPERIMENT TITLE: Rechargeable Lithium Battery Power System

PURPOSE: Evaluate the performance of a high specific energy rechargeable power source (lithium base battery) in LEO flight environment with associated power hardware to assess the fasibility of becoming a viable secondary power source.

PROPOSED FLIGHT DATE (Year) 1992 or later

OPERATIONAL DAYS REQUIRED 1-2 years

APPROXIMATE MASS (Kg) 10.5 kg

VOLUME:

STOWED: L____ x W____ x H____ = .007 Cu.M.

DEPLOYED: L____ x W____ x H____ = .007 Cu.M.

REQUIRED ORIENTATION (Inertial, solar, earth, other): N/A

EXTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: N/A Hrs/Day N/A No. of Days

OPERATIONS: N/A Hrs/Day N/A No. of Days

SERVICING: N/A Hrs/Day --- No. of Days

INTRA-VEHICULAR ACTIVITY REQUIRED:

SET-UP: N/A Hrs/Day N/A No. of Days

OPERATIONS: 24 Hrs/Day 365+ No. of Days

SERVICING: N/A Hrs/Day --- No. of Days

POWER REQUIREMENTS:

AVERAGE: 150 wattsKW PEAK: N/A KW DC X
AC ____ HZ ____

Hrs/Day: 24 No. of Days: 365+

DATA STORAGE: TAPE STORAGE X OR IN-SITU TRANSMISSION X NONE ____

DIRECT CONTROL FROM EARTH REQUIRED: YES ____ NO X

OTHER REQUIREMENTS: 1-Remove the experiment if failure of more than two battery cells is noted.

2-Temperature control, battery operating range, 10-30^{o}C.

SUBJ.: CONCEPTIONAL DESIGN AND POSSIBLE TEST NEEDS FOR A
PHOTOVOLTAIC POWER TEST BED

DEAR MR. NEFF,

IN ADVANCE THE INFORMATION FOR YOU FOR EXPERIMENTS IN SPACE. WE ARE INTERESTED IN THE FOLLOWING THREE EXPERIMENTS CALLED

- BIFACIAL CELL FOR THE SPACE
  IT SHALL BE PROVEN THE ADVANTAGE OF THIS CELL COMPARED TO THE CONVENTIONAL CELL. IT USES THE ALBEDO-RADIATION. THEREFORE THE EFFECTIVE EFFICIENCY OF THIS CELL TYPE IS HIGHER. HOWEVER IT CAN BE MORE SENSITIVE AGAINST ELECTRON AND PROTON IRRADIATION, BIHEEGHBRE THE DEGREASESONNCOUL
  POWER OUTPUT AND THE HIHER DEGRADATION RATE SHALL BE DETERMINED.

- INFLUENCE OF PROTON IRRADIATION ON THE PN-JUNCTION OF SILICON SOLAR CELLS

  THE INFLUENCE OF THE PROTON IRRADIATION ON THE ELECTRICAL PARAMETERS OF SOLAR CELLS SHALL BE INVESTIGATED FOR DIFFERENT PN-STRUCTURES.

- NEW CELL STRUCTURES FOR THE SPACE

  THE ELECTRICAL CHARACTERISTICS AND THE DEGRADATION BEHAVIOUR OF THE GAAS SOLAR CELL AND/OR OF THE INVERSION LAYER-SOLAR CELL AND/OR THE AMORPHOUS SOLAR CELL SHALL BE INVESTIGATED.

THE FOLLOWING MEASUREMENTS AND ANALYSIS ARE NECESSARY

- CURRENT-VOLTAGE-CHARACTERISTICS
- CELL TEMPERATURE
- INCIDENT SOLAR ENERGY
- INCIDENT ELECTRON AND PROTON IRRADIATION (DOSIS AND DENSITY)
- FOR THE P-GRID CELL IT IS DESIRABLE IF THE CELL COULD BE ROTATED.

FOR THE EXPERIMENTS WEE NEED A SPACE OF 60 CM X 100 CM. THE MASS OF THE SOLAR GENERATORS WILL ABOUT 500 -600 YMS.

IM JANUARY YOU WILL GET THE FILLED AP FORMULA AND SOME MORE DETAILS.

I HOPE THESE INFORMATIONS ARE USEFUL FOR YOUR FIRST STUDY.

WE BEST REGARDS AND BEST WISHESFOR THE NEW YEAR
TELEFUNKEN ELECTRONIC
7100 HEILBRONN
DR. ROY-SR

Ymsc				FACC/WDL CORRESPONDENCE MESSAGE CENTER	
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◄ Space Technology ►

Pilkington P.E. Limited
Kinmel Park Industrial Estate Bodelwyddan Rhyl Clwyd LL18 5TY U.K.
Telephone St Asaph (0745) 584584 Telex 61532

Mr. Robert E. Neff,
Engineering Specialist - Space Systems,
FORD AEROSPACE & COMMUNICATIONS CORP.,
Western Development, Laboratories Division,
3939 Fabian Way,
PALO ALTO,
California 94303
United States.

26th February, 1986.

Dear Mr. Neff,

In response to your letter of 31st October 1985 to Dr. C. Kitchen regarding our likely requirements for a photovoltaic power test bed as part of the Space Station overall concept, I have the pleasure of putting forward some of Pilkington Space Technology's ideas and concepts.

The concepts that we are suggesting are, we feel, representative of 1990's technology and therefore are hard to quantify onto the summary sheets at this stage. In general terms the experiments we would propose submitting in the period 1992-95 are:-

(1) Concentrators - this would involve large area, ultra light reflectors either passive or active e.g., solar dynamic. Alternatively, this may involve diffractive optics - e.g., large area holographic lenses, as a means of concentration. A panel area of several (approx 5) square meters would be used with a mass of a number of kilogrammes. The experiment would be passive, ie., no activity apart from deployment would be required. The performance of the modules would be monitored and recorded.

(2) Solar Cell Protection - this will involve alternative methods of bonding coverglasses to solar cells. Possible methods include FEP Teflon and electrostatic bonding and also RF sputtering. In addition, alternative materials to glass may also be available for testing.

The experiment would utilise a small panel area of approximately $1m^2$ and only require deployment and periodic inspection. The performance would be monitored and the cell output recorded.

Continued......

(3) Solar Cell Annealing - the possibility of using laser annealing to regenerate the solar cells following damage by radiation bombardment. This may require alternative types of coverglass. As in (2) the experiment would require a small panel area of approximately $1m^2$. Following a period in orbit after deployment, the panel would be subjected to laser annealing - the performance being monitored throughout.

At present these three concepts are the most obvious to us. However, I am confident that in the intermediate time between now and the 1990's other technological experiments and opportunities will become apparent.

We would welcome any further comments or information that you may have and would wish to be actively involved in any subsequent discussions or work studies.

Yours sincerely,

P. White.

Peter White
Project Engineer.

SIX WEEK REVIEW SUMMARY

SPACE STATION EXPERIMMENT DEFINITION:

ADVANCED POWER SYSTEM TEST BED

6 DECEMBER 1986

POWER GENERATION	INTERESTED ORGANIZATIONS: INDUSTRY	DOD	NASA	JPL		PURPOSE: FLIGHT	QUAL	CONCEPT	DEMO	STS FLIGHT NEEDED
Planar Array										
1) High voltage effects (Plasma Interactions)		X	X			X		X		planned
2) Albedo utilization		X	X			X		X		
3) Flex blanket		X	X			X				
Concentrator Array										
1) TRW Cassegranian		X	X			X		X		
2) GE		X	X			X		X		
3) GD Slats		X	X			X		X		
Solar Cells										
1) GaAs	X	X	X			X				
2) Multiple Junction	X	X	X			X		X		X
3) Plasmon			X					X		X
4) Albedo Utilization		X	X					X		X
ENERGY STORAGE										
1) Li/TiS2 Battery	X	X	X			X		X		
2) NiH2 Bipolar	X	X	X			X		X		X
3) NaS Battery						X		X		
4) H2/X2 RFC						X		X		
5) N2H4 APU								X		
6) Flywheels								X		
POWER MANAGEMENT & DISTRIBUTION										
1) Testing of High Voltage/ High Power Handling Equipment		X	X			X		X		
2) Electromagnetic Interference - Static Charge arc Discharge		X	X			X		X		
3) Microwave Power Transfer		X	X					X		

*** List of Potential Experiments ***

EXPERIMENT 1. SOLAR ARRAY, CONVENTIONAL

OBJECTIVE - HIGH VOLTAGE ARRAY - PLASMA INTERACTION

TEST ITEM - PLANER SOLAR ARRAY, SS TECHNOLOGY

APPROXIMATE SIZE - PANEL SIZE 0.366 X 4.2 M

- PANEL VOLTAGE 80 VDC

14 PANELS = 1000 VOLTS, THEREFORE, MINIMUM SIZE

4.2 X 5.1 M AND PRODUCES 2.3 KW

TWO ARRAYS PROVIDE CONTROL AND VARIABLE SET-UP

TEST VARIABLES - ARRAY VOLTAGE, +/- 1000 VDC

- SUBSTRATE GROUNDING

MEASUREMENTS - PLASMA DENSITY, ARRAY I AND V

EXPERIMENT 2. POWER SYSTEM GROUND

OBJECTIVE - MINIMIZE PLASMA CHARGE ON PV POWER SYSTEM

- INCREASE POWER SYSTEM EFFICIENCY AND EVA SAFETY

TEST ITEM - TEST BED PV ARRAY - ESS - PMAD

APPROXIMATE SIZE - TEST BED DEFINED IN EXPERIMENT 1

- ABLE TO OBTAIN +/- 1000 VDC

TEST VARIABLES - ISOLATION OR CONNECTED GROUND

- POSITIVE, NEGATIVE, INTERMEDIATE

MEASUREMENTS - PLASMA DENSITY

- POWER SYSTEM OPERATING CHARACTERISTICS

EXPERIMENT 3. CONCENTRATOR ARRAY

OBJECTIVE - CONCENTRATOR TECHNOLOGY VERIFICATION

TEST ITEM - TRW MINIATURE CASEGRANIAN

- GE AND GD ALTERNATE DESIGNS

APPROXIMATE SIXE - 40 SUBPANELS OF 0.7 X 0.7 M PANEL

CONFIGURATION 3 X 7.6 M AND PRODUCES 2.3 KW

ALTERNATE ARRAY CONTENTIONAL PLANER FOR COMPARISON

TEST VAERIABLES - VOLTAGE VS PLASMA

- POINTING

- STABILITY OF OPTICCS

- STABILITY, PLANARITY OF STRUCTURE

- ADVANCED SOLAR CELL CONFIGURATION

MEASUREMENTS - SUN SENSORS TO RESOLVE POINTING OF STRUCTURE

- ELECTRICAL OUTPUT, PLASMA DENSITY

EXPERIMENT 4. ENERGY WHEEL

OBJECTIVE - PERFORMANCE VERIFICATION

TEST ITEM - COUNTGER ROTATING AFLYWHEEL ASSEMBLY, 4 KW UNIT

APPROXIMATE SIZE - A 4 KW UNIT IS 0.5 X 0.5 X 1.0 METER

- MASS ABOUT 200 KG WITHOUT ELECTRONICS

TEST VARIABLES - NORMAL CHARGE/DISCHARGE

- PEAK LOAD CAPABILITY

- LIFETIME IN ZERO GRAVITY

- ADVERSE OPERATION

MEASUREMENTS - RESULTANT FORCES TO TEST BED

- INPUT/OUTPUT ELECTRICAL CHARACTERISTICS

EXPERIMENT 5. AMORPHOUS SILICON ARRAY

OBJECTIVE - ENVIRONMENTAL STABILITY

TEST ITEM - INTEGRAL AROLL UP CELL ASSEMBLY

APPROXIMATE SIZE - 2 M WIDE, 10 M LONG BLANKET TO DELIVER 1.4 KW, ESTIMATED WEIGHT WITH DEPLOYMENT UNIT IS 400 KG

TEST VARIABLES - DEPLOYMENT/RETRACTION

- HIGH TEMPERATURE ANNEALING

MEASUREENTS - ARRAY CURRENT, VOLTAGE, TEMMPERATURE

- PLASMA DENSITY

EXPERIMENT 6. HIGHT ENERGY DENSITY/CHARGE EFFICIENCY NaS BATTERY

IBJECTIVE - NaS BATTERY PERFORMANCE VERIFICATION

- WICKING OF MOLTEN Na TO ELECTROLITE

- WICKING OF MOLTEN S/Na POLYSULFIDE

TEST ITEM - NaS CELLS AND THERMAL CONTROL

- INTERFACE WITH TEST BED POWER SYSTEM

APPROXIMMATE SIZE - 0.7 M DIA X 0.5 M HIGH WITH ESTIMATED MASS OF 100 KG, FOR 2 KW

TEST VARIABLES - COLD LAUNCK, 350 C OPERATION

- MULTIPLE CHARGE-DISCHARGE CYCLES

MEASUREMENTS - CHARES/DISCHARGE CURRENT AND VO9LTAGE

- TEMPERATURE

EXPERIMENT 7. HIGH SPECIFIC ENERGY, Li/TiS2 BATTERY

OBJECTIVE - PERFORANCE VERIFICATION

- ZERO GRAVITY ELECTROLYTE BEHAVIOR

TEST ITEM - SELF CONTAINED ACELL MODULE, JPL

APPROXIMATE SIZE - 1.0 X 0.5 X 0.5 M WITH MASS 100 KG, 1 KW UNIT PLUS LARGE RADIATOR AND THERMAL SYSTEM

TEST VARIABLES - MULTIPLE CHARGE/DISCHARGE CYCLES

MEASUREMENTS - CURRENT, VOLTAGE, TEMPERATURE

EXPERIMENT 8. HYDROGEN-BROMINE REGENERATIVE FUEL CELL

OBJECTIVE - BROMINE PERFORMANCE IN ZERO GRAVITY

- ADEQUATE CONTACT OF HBr/Br TWO PHASE MIXTURE WITH METALIC AND SEPARATOR SURFACES

- SEPARATION AND STORAGE OF Br2 AND HBr

- DATA BASE FOR HIGH EFFICIENCY, 80% SYSTEM

TEST ITEM - FUEL CELL WITH ACTIVE THERMAL CONTROL

APPROXIMATE SIZE - 1.0 X 0.5 X 0.5 M, MASS 200 KG FOR 2 KW UNIT

TEST VARIABLES - MULTIPLE CHARGE/DISCHARGE CYCLES

MEASUREMENRTS - CURRENT, VOLTAGE, PRESSURE, ELECTROLYTE CONCENTRATION

EXPERIMENT 9. NiH2 BIPOLAR BATTERY

OBJECTIVE - PERFORMANCE VERIFICATION OF COMPACT, MODULAR UNIT

- REDISTRIBUTION OF ELECTROLYTE AT LAUNCH

TEST ITEM - NiH2 BIPOLAR BATTERY WITH ACTIVE COOLING

APPROXIMMATE SIZE - 1.5 X 0.4 X 0.4 M, MASS 300 KG

5 KW UNIT, PLUS THERMAL CONTROL

TEST VARIABLES - MULTIPLE CHARGE/CISCHARE CYCLES

MEASUREMENTS - CURRENT, VOLTAGE, TEMPERATURE, PRESSURE,

COOLING FLOW RATE

EXPERIMNT 10. HIGH VOLTAGE/POWER PMAD

OBJECTIVE - DEMONSTRATION OF PERFORMANCE IN PLASMA

- ATTRACTION OF SPACE DEBRIS WITH RESULTING

SHORT OF HIGH VOLTAGE CIRCUITS

TEST ITEM - HIGH VOLTAGE/HIGH POWER CHARGE CONVERTER

APPROXIMATE SIZE - 0.3 X 0.5 X 0.6 M, MASS 30 KG FOR 5 KW UNIT

TEST VARIABLES - OPERATING VOLTAGE AND EXPOSURE TIME

MEASUREMENTS - ELECTRICAL PARAMETERS UNDER LOAD

EXPERIMENT 11. MICROWAVE POWER TRANSFER

OBJECTIVE - TEST EFFICIENCY OF POWER TRANSFER FROM STATION TO PLATFORM

- DETERMINE RF FIELD INTERACTIONS

TEST ITEM - HIGH POWER-HIGH FREQUENCY TRANSMITTER, ANTENNA AND RECEIVER

APPROXIMMATE SIZE - 1 TRANSMITTER, 0.3 X 0.3 X 0.6 M, 50 KG

2 ANTENNAS, 1.5 M DIA,. 35 KG EACH

1 RECEIVER, 0.3 X 0.3 X 0.6 M, 50 KG

2 TO 4 KW POWER INPUT

TEST VARIABLES - TRANSMISSION FREQUENCY 1 TO 100 GHZ

- POINTING ACCURACY

- PLASMA ABSORPTION

MEASUREMENTS - PLASMA DENSITY, POWER IN/OUT, POINTING ANGLE

TABLE 1.

SIZING OF TEST BED

EXPERIMENT	OPERATING POWER 1 KW-	2 KW	3 KW	4 KW	5 KW	6 KW+
1. PV-PLASMA		X				
2. GROUND		X				
3. CONCENTRATOR		X				
4. ENERGY WHEEL				X		
5. AMORPHOUS Si	X					
6. NaS BATTERY		X				
7. Li/TiS2 BATTERY	X					
8. H2-Br BATTERY		X				
9. NiH2 BATTERY					X	
10. HI VOLT PMAD					X	
11. MICROWAVE POWER			X			

TABLE 2.

MAJOR COMPONENTS OF TEST BED - PRELIMINARY

MECHANICAL - FIXED PALLET FOR ESS, PMAD, THERMAL, DATA

- SUN ORIENTED PLATFORM OR ATTACHMENT
- MSC CAPABILITY
- ALPHA AND BETA JOINTS FOR POWER/DATA TRANSFER

ELECTRICAL - MODULARITY OF POWER CONVERTERS FOR ESS MGMT

- SOLAR ARRAY VOLTAGE REGULATION UNIT
- POWER MANAGEMENT AND DISTRIBUTION UNITS
- SLIP RINGS ACROSS BETA JOINT

THERMAL - THERMAL FLUID LOOP ON FIXED PALLET

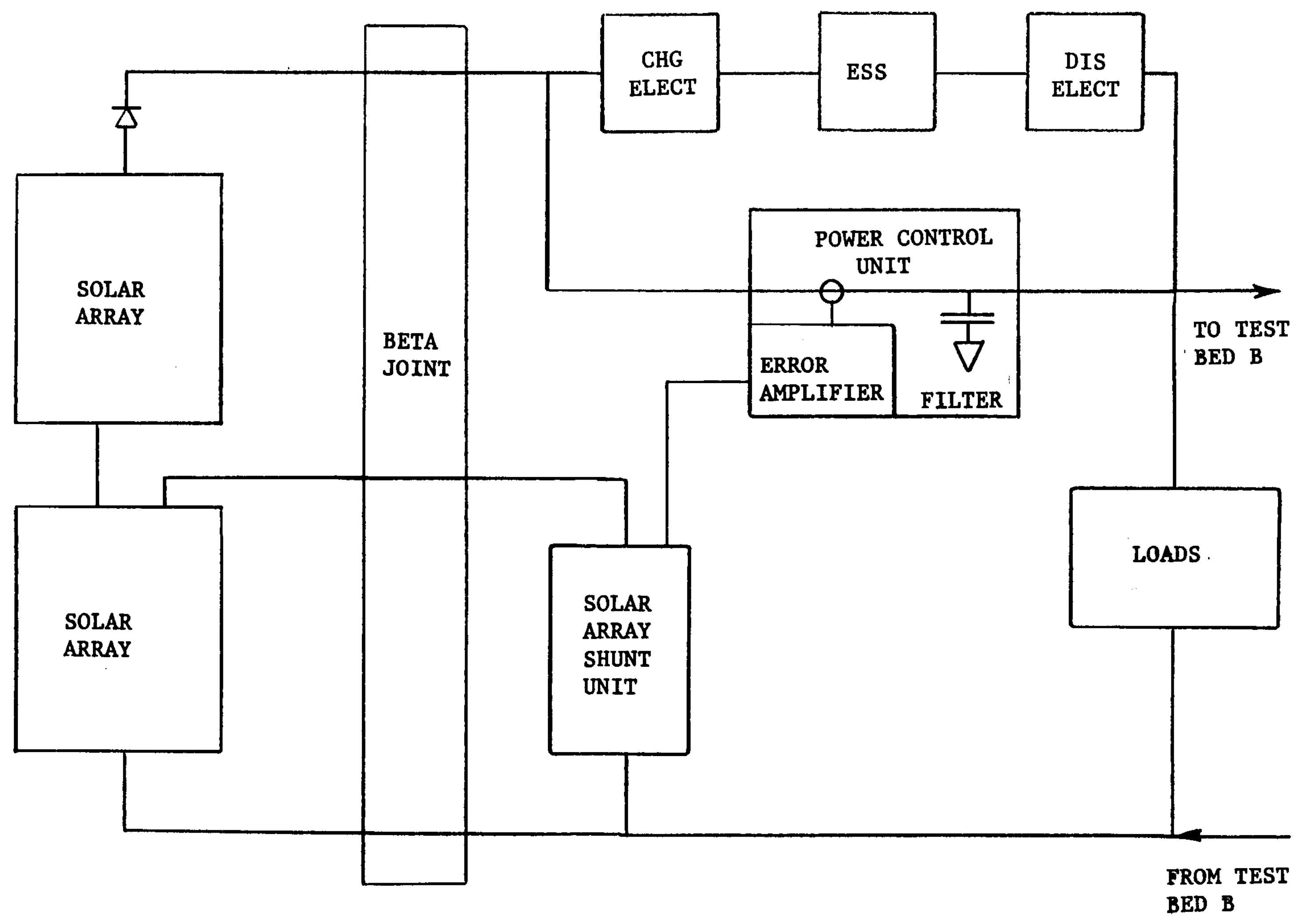
- POWER SUPPLY AND CONTROLLER FOR RESISTANCE HEATERS
- THERMAL BLANKET ATTACHMENTS
- THERMAL INSTUMENTATION

DATA/CONTROL - MICROPROCESSOR FOR DATA, TEST, AND CONTROL

- DMS INTERFACE

INSTRUMENTATION - LANGMUIR PROBE, DENSITY AND PLASMA TEMP

- SUN SENSOR



ELECTRICAL SYSTEM BLOCK DIAGRAM

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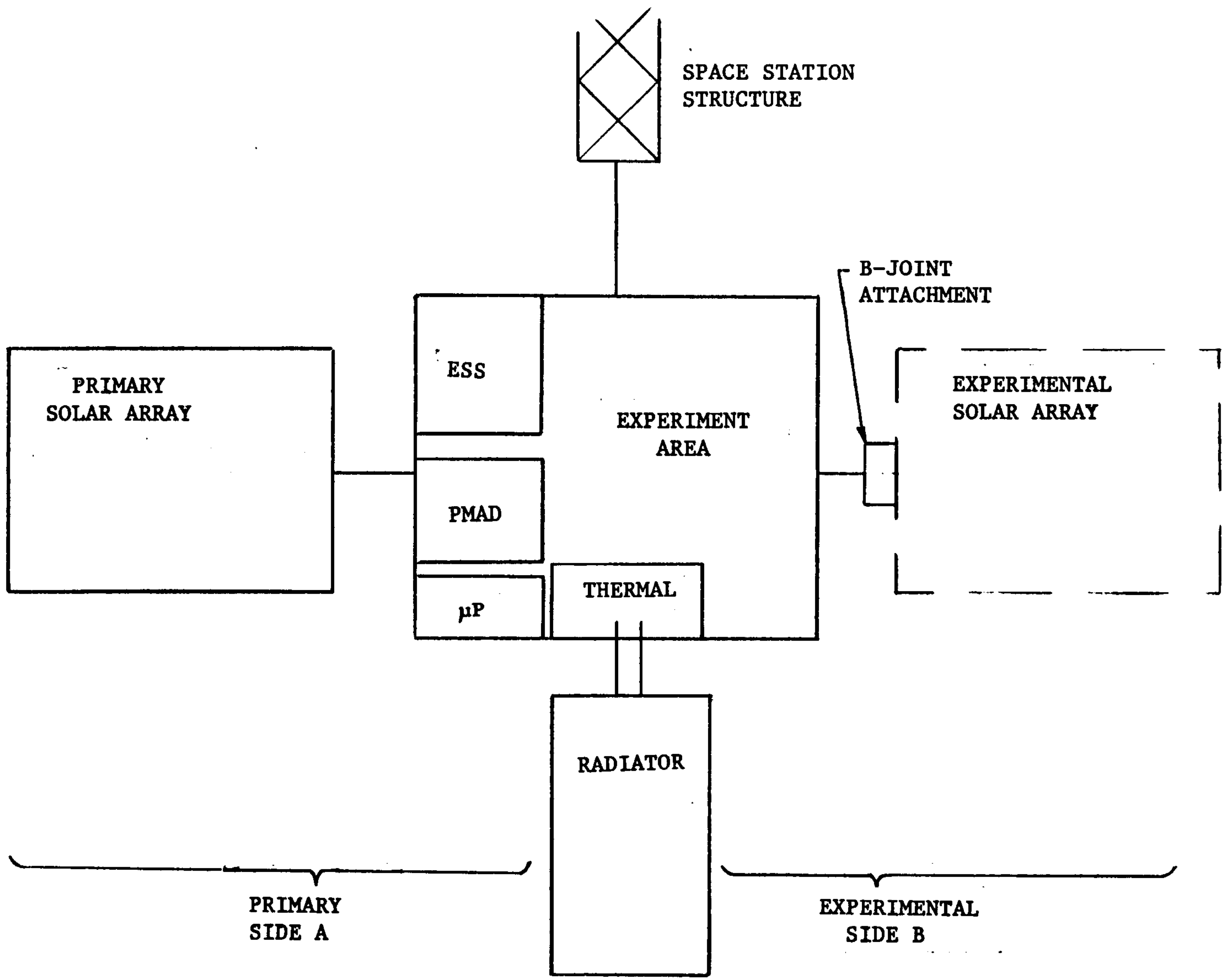

TEST BED - A CONCEPTUAL DESIGN

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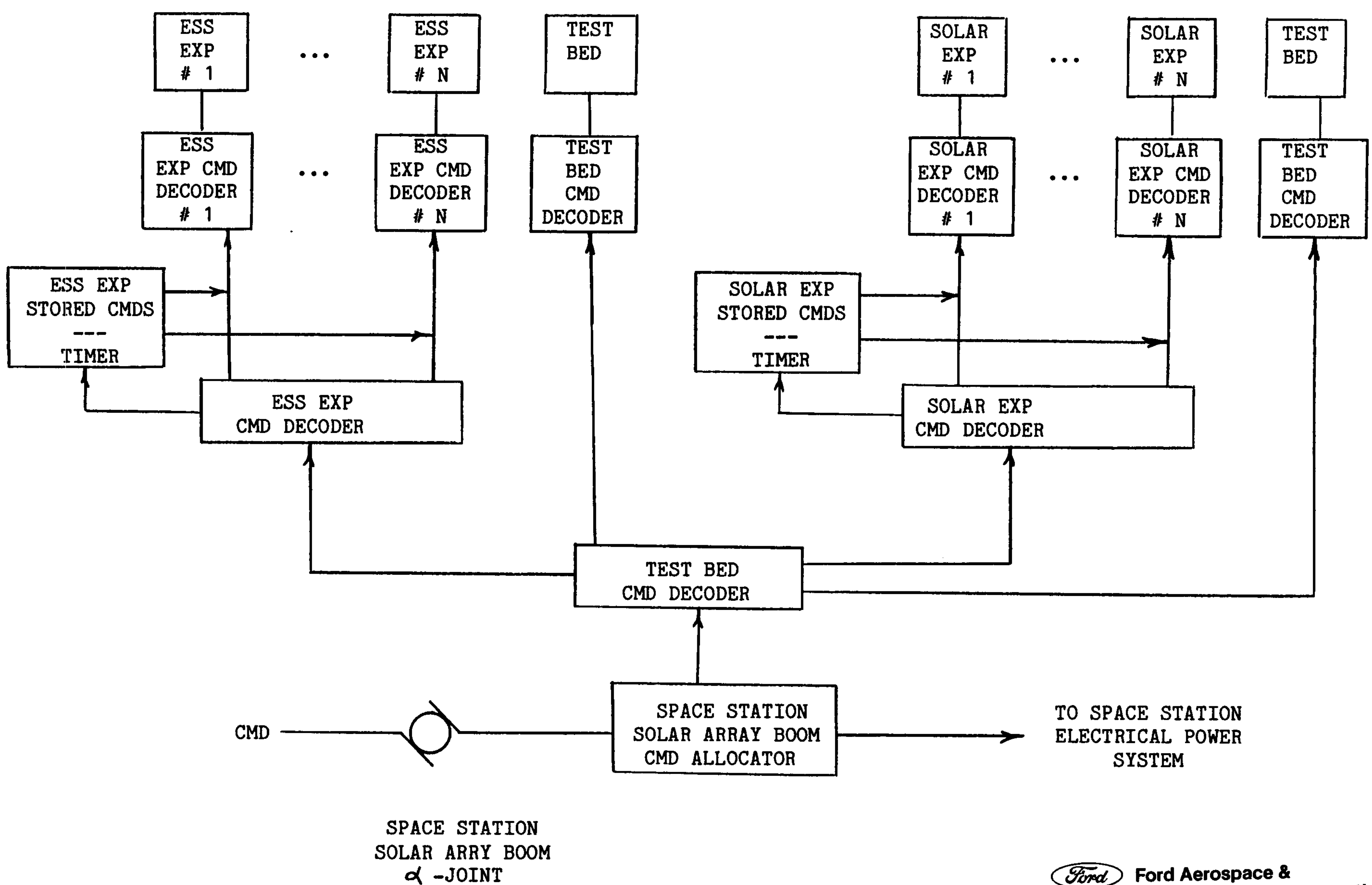
APPENDIX 2.

- Three Month Review Summary

TEST BED SITE TRADE STUDY

LOCATION	PRO's	CON's
END OF SOLAR ARRAY BOOM	o SS ALPHA JOINT PROVIDES FULL VIEW OF SUN o DEEP VIEW OF SPACE (THERMAL)	o INSTALLATION/REMOVAL REQUIRES EVA o POSSIBLE ATTITUDE CONTROL IMPACT DUE TO MASS IMBALANCE
UPPER BOOM	o RMS ACCESS FOR SOME TASKS	o POSSIBLE RCS CONTAMINATION o HIGH DEMAND REAL ESTATE
UPPER KEEL/INNER SOLAR ARRAY BOOM	o RMS ACCESS FOR SOME TASKS o LESS SHADOWING ON SS SOLAR ARRAY THAN UPPER BOOM	o POSSIBLE RCS CONTAMINATION o SHADOWS FROM SS APPROXIMATELY 50 % OF YEAR
TWO PART CONFIGURATION PV and ENERGY STORAGE	o MINIMIZES UPPER BOOM DEMANDS o MINIMIZES 'END OF BOOM' COMMANDS ACROSS ALPHA JOINT	o COMPLICATES DESIGN o INCREASES COST

TYPICAL COMMAND SYSTEM - END OF SOLAR ARRAY BOOM



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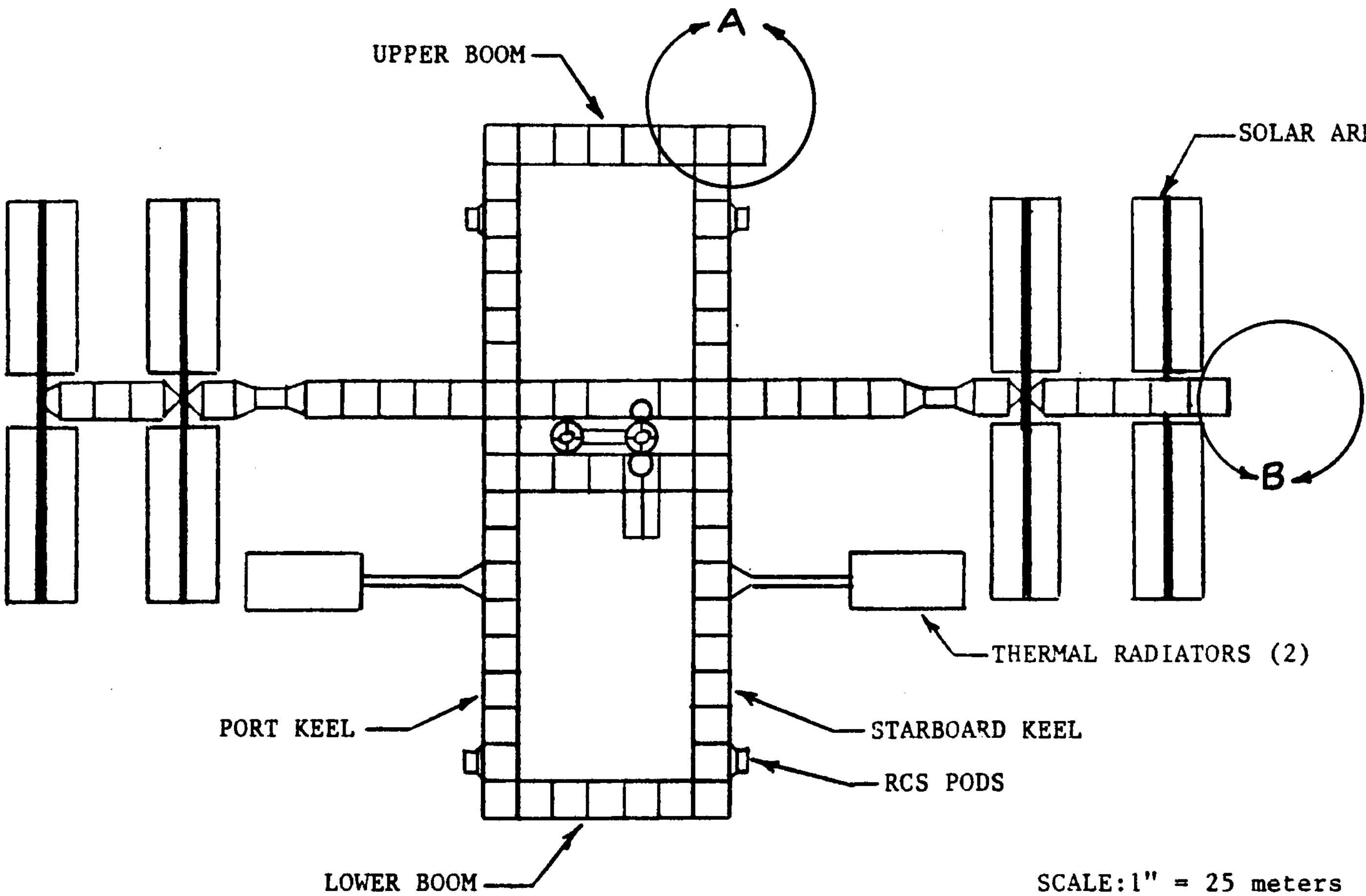
SAFETY

POTENTIAL HAZARDS	SOLUTIONS
HIGH TEMPERATURE RADIATORS - DUMMY LOAD ELEMENTS - THERMAL CONTROL LOOPS	o REMOTE LOCATION FOR HAZARDOUS HARDWARE o EVA PRE-OPERATIONS CHECKLIST
HIGH TEMPERATURE EXPERIMENTS - NaS BATTERIES	o WARNING LABELS o PROTECTIVE CONTAINERS
SOLAR ARRAY EXPERIMENTS - HIGH VOLTAGE - REVERSE BIASED CELLS - HIGH TEMPERATURE COMPONENTS	o RECONFIGURATION TO SAFE MODE o LIMIT SIZE o DELETE EXPERIMENT
PMAD - HIGH VOLTAGES	
OTHER - ENERGY WHEEL (HIGH SPEED) - Li/TiS2 (EXPLOSIVE)	

SPACE STATION CONFIGURATION



SCALE: 1" = 25 meters

= 115 feet

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TEST BED ENERGY STORAGE EXPERIMENTS

THERMAL REQUIREMENTS

EXPERIMENT	DISCHARGE POWER (WATTS)	DISCHARGE HEAT (WATTS)	RADIATOR TEMP (C)	EXPERIMENT TEMP CONTROL RADIATOR AREA (SQ.M)	ELECTRONICS TEMP CONTROL RADIATOR AREA (SQ.M)	DUMMY LOAD RADIATOR AREA (SQ.M)	TOTAL (SQ.M)
LiTiS2	1000	300	15	.96	.17	.15	1.28
NaS	2000	700	350	.20	.34	.30	.84
NiH2 BIPOLAR	5000	1250	0	4.95	.85	.75	6.55
H2BR2 RFC	2000	600	85	.80	.34	.30	1.44
H2O2 RFC	2000	1500	85	2.00	.34	.30	2.64
FLYWHEEL	4000	480	35	1.16	.68	.60	2.44

TIME PHASED TEST PLAN

MAJOR EXPERIMENTS	1992	1993	1994	1995	1996	1997	1998
1. PV-PLASMA (1)	******		**********		**********	**********	**********
2. GROUNDING	***						
3. PV-CONCENTRATOR (2)	****	**********					
4. ENERGY WHEEL		***					
5. THERMOPHOTOVOLTAIC				**********			
6. BATTERY-NaS	****		**********				
7. TIME ANNEALING	***---->						
8. BATTERY-Li/TiS2				**********			
9. BATTERY-Ni/H2 (3)	***---->						
10. MICROWAVE POWER					******		
11. H2/Br REG. FUEL CELL							*****

(1) PRIMARY ARRAY TO BE IN PLACE DURING ABSENCE OF EXPERIMENTAL ARRAYS
(2) CASSIGRAINIAN, SLATS, FRESNEL, NEWTON
(3) TO REMAIN PART OF PRIMARY TEST BED FOLLOWING EXPERIMENTAL PHASE

TIME PHASED TEST PLAN

MINOR EXPERIMENTS	1992	1993	1994	1995	1996	1997	1998
1. HI VOLTAGE PMAD			*****				
2. ALBEDO - GBC CELLS		***					
3. DEPLOYMENT/RETRACTION	**		**				
4. PV-AMORPHOUS Si				**********			
5. NEW TECH CELL QUAL.		***		***		***	
6. REAL TIME CELL DEG.	***---->						
7. ON ORBIT ARRAY REPAIR	******						
8. STANDARDS CALIBRATION	**		**		**		**

APPENDIX 3.

- Detailed Conceptual Equipment Design

COMPARISON OF RESOURCES ON TEST BED AND FREE FLYER

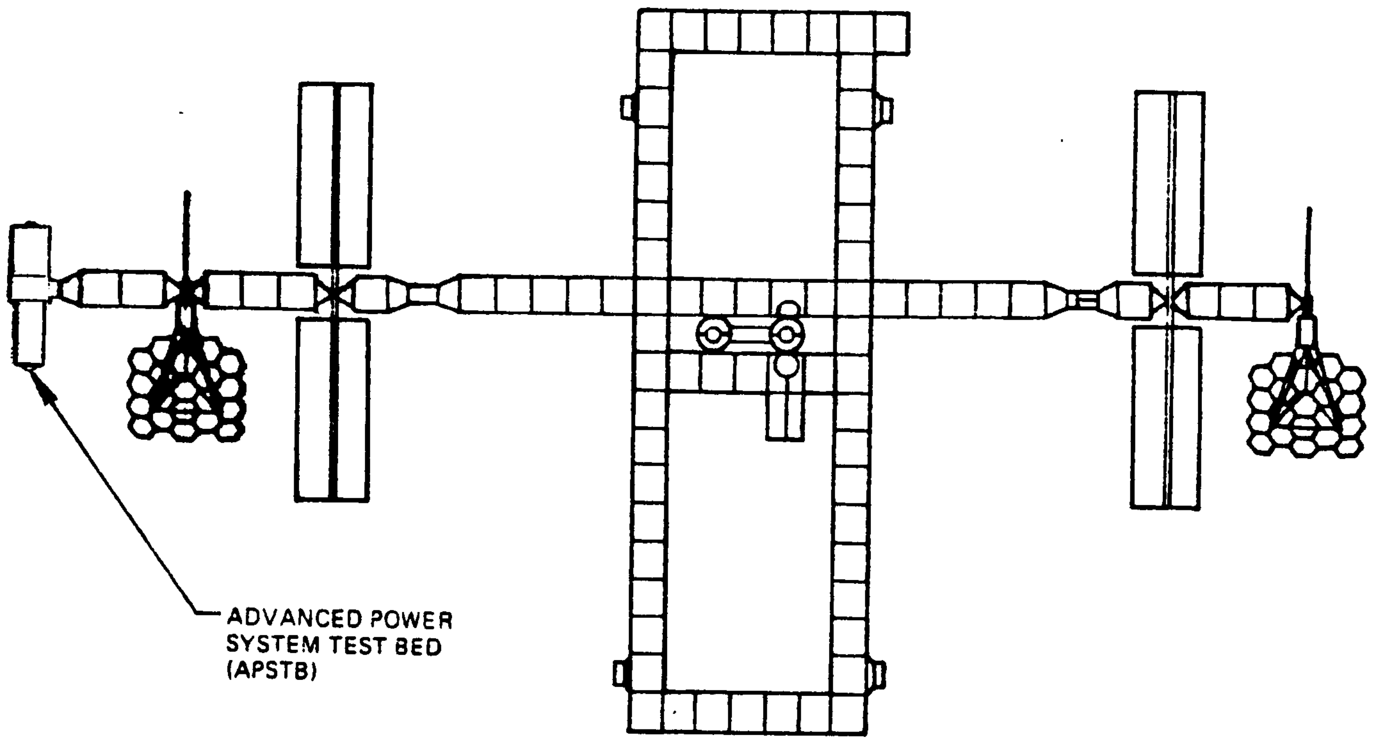
	SPACE STATION (SS)	FREE FLYER
COMMAND/TELEMETRY	AVAILABLE	AVAILABLE
ELECTRICAL POWER	AVAILABLE *	MORE LIMITED THAN SS **
SOLAR ILLUMINATION AREA	AVAILABLE	MORE LIMITED THAN SS **
THERMAL	AVAILABLE IF NEEDED *	
EVA OR RMS ACCESSABILITY	AVAILABLE SCHEDULING FLEXIBLE	AVAILABLE AT RETRIEVAL

* ASSESSMENT REQUIRES CONSIDERATION OF DATA BASE ON ALOCATION OF RESOURCE.

** COMPARISON REQUIRES QUANRTIFICATION, AND COMPARISON WITH EXPERIMENT REQUIREMENTS.

END OF SOLAR ARRAY BOOM

SIZE COMPARISON WITH SPACE STATION



APSTB LOCATED ON SPACE STATION

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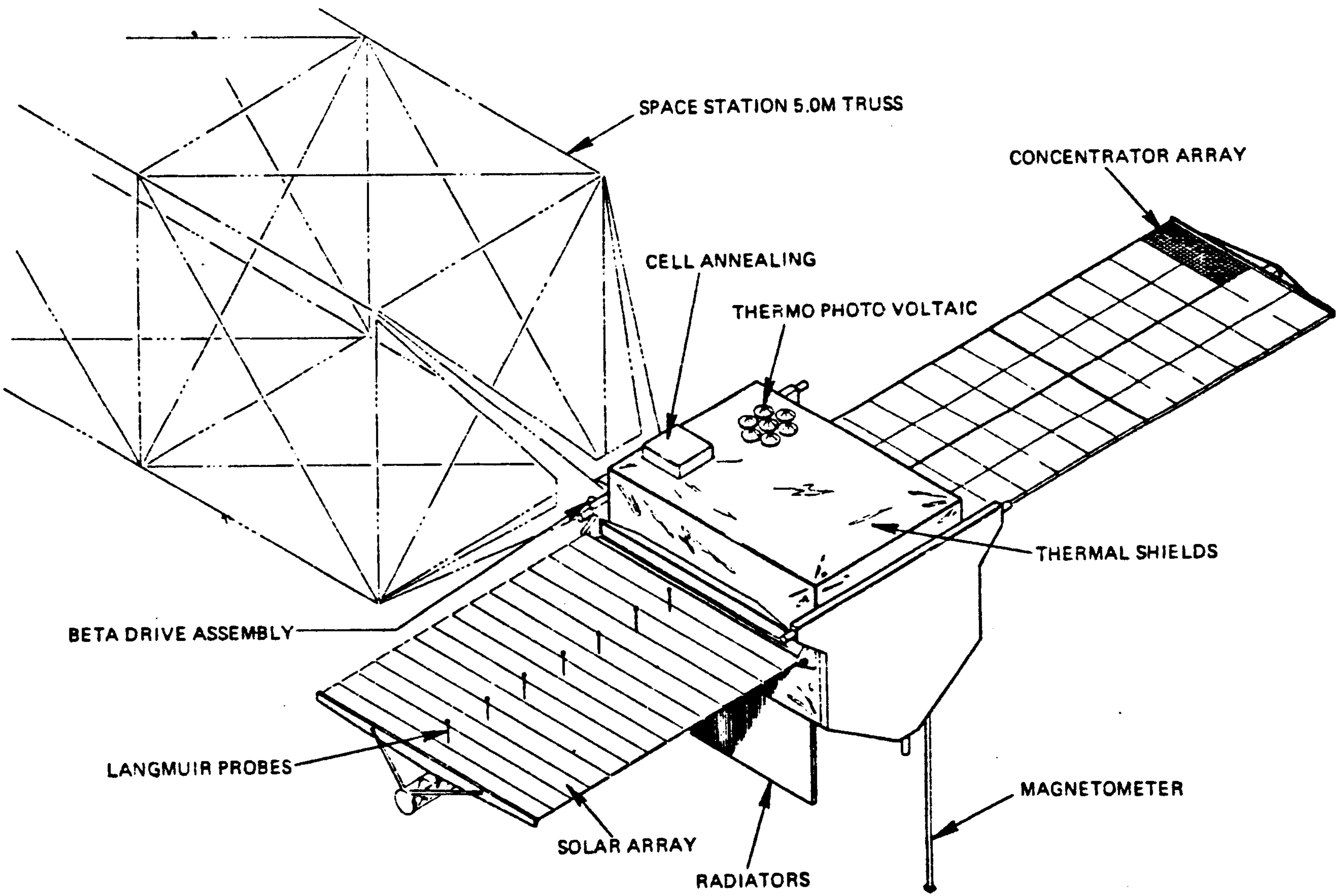
END OF SOLAR ARRAY BOOM
CONFIGURATION DEPLOYED



APSTB CONFIGURATION

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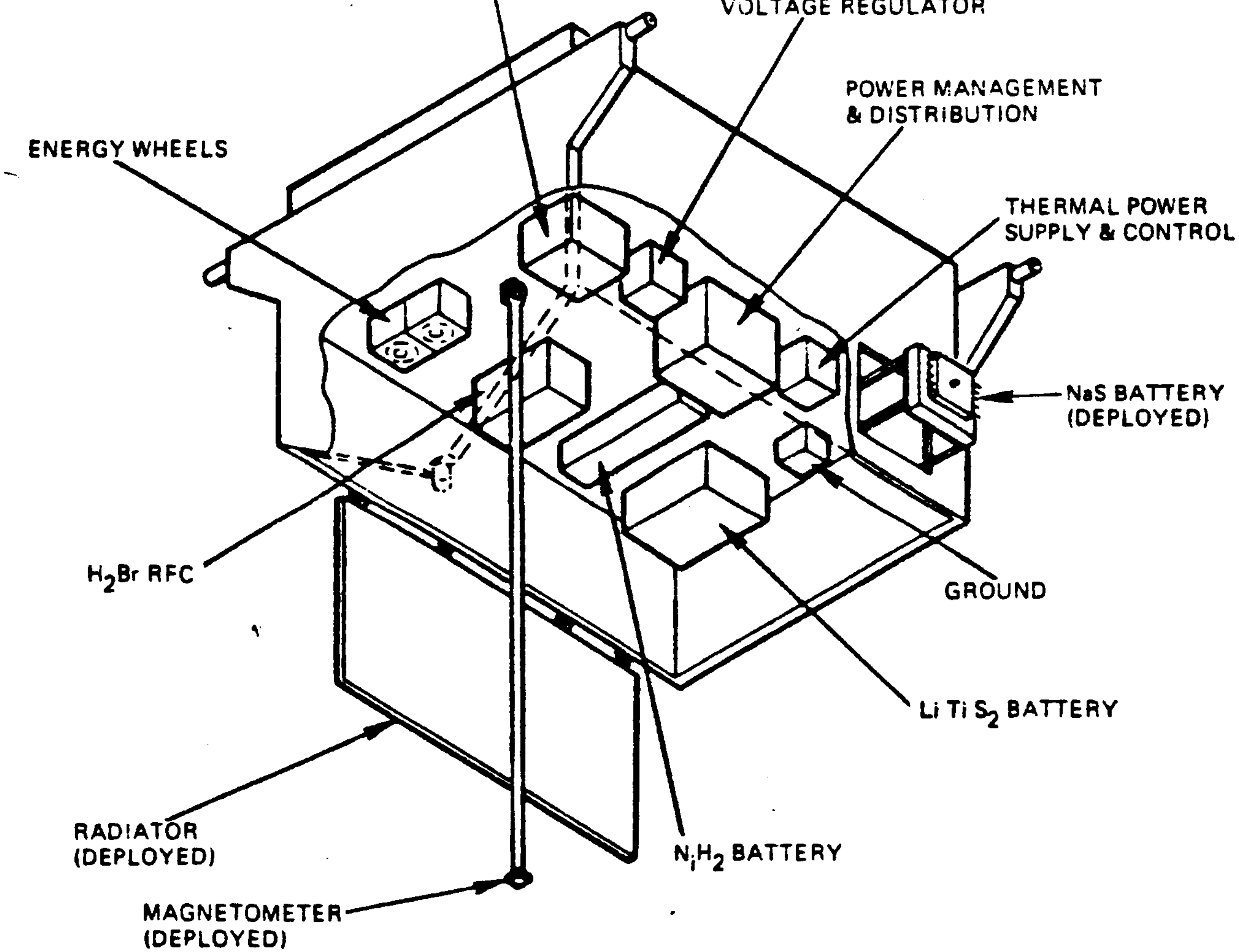
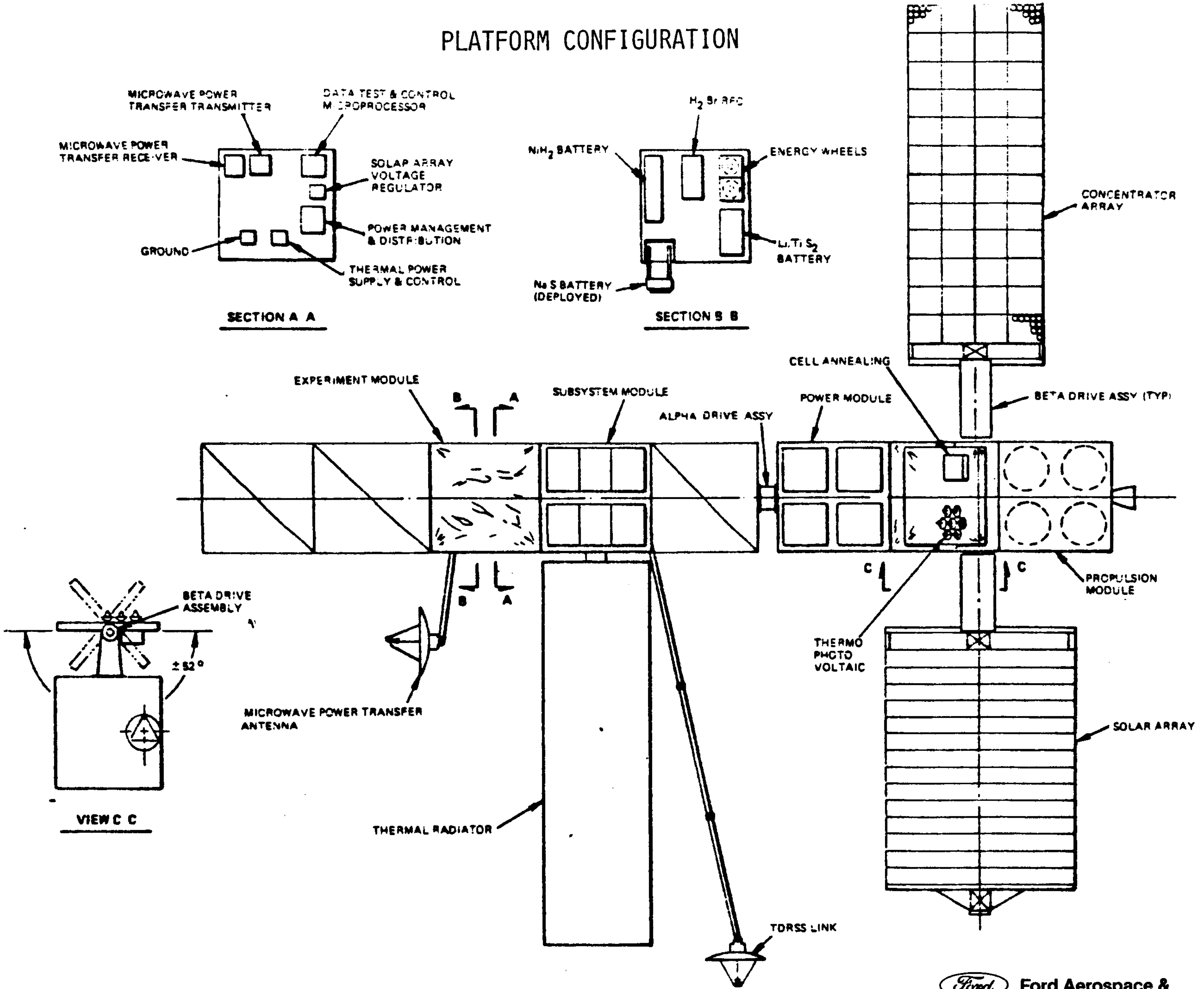
END OF SOLAR ARRAY BOOM

CONFIGURATION DEPLOYED



APSTB LOWER EXPERIMENT MODULE

PLATFORM CONFIGURATION



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APPENDIX 4.

- Preliminary Evolutionary Plan

NASA LEVELS OF TECHNOLOGICAL MATURITY

LEVEL 1. BASIC PRINCIPLES OBSERVED AND REPORTED.

LEVEL 2. CONCEPTUAL DESIGN FORMULATED.

LEVEL 3. CONCEPTUAL DESIGN TESTED ANALYTICALLY OR EXPERIMENTALLY.

LEVEL 4. CRITICAL FUNCTION BREADBOARD DEMONSTRATION.

LEVEL 5. COMPONENT OR BRASSBOARD MODEL TESTED IN RELEVANT ENVIRONMENT.

LEVEL 6. COMPONENT OR ENGINEERING MODEL TESTED IN RELATIVE ENVIRONMENT.

LEVEL 7. ENGINEERING MODEL TESTED IN SPACE.

LEVEL 8. BASELINED INTO PRODUCTION DESIGN.

IDENTIFICATION OF PRECURSOR ACTIVITIES

Experiment/Measurements	Maturity Level	Tasks To Do	Vendor
1. Plasma Interaction - High voltage Plasma Interaction	2	- Shuttle flight o VOLT o Interaction with S/A Segments - Test Bed o Planning based upon Shuttle flight	LMSC *Sharp
2. High Voltage PMAD - Plasma Interaction - System efficiency - System safety	2	- Shuttle flight and Test Bed o Testing of voltage biased hardware	
3. Solar Array - Concentrator - Verify Technology in Space o Deployment o Pointing Accuracy o Power capability o Protective Coatings	4	- Ground Test EM - Shuttle Flight o Deploymentycle o Pointing Accuracy o Power Capability - Test Bed o Protective Coatings o Long term performance	GE TRW *Aerospatiale
4. Energy Wheel - Concept Demonstration o Power capability - Safety	3	- Technology is not fully Conceptualized. o Planning is TBD	

* Inputs Received From Letter Survey

IDENTIFICATION OF PRECURSOR ACTIVITIES (CONT)

Experiment/Measurements	Maturity Level	Tasks To Do	Vendor
5. Amorphous Silicon Array - Degradation - Power Density - Annealing - Retractability - Power Output	4	- Ground Test EM o 1 MeV electron o Annealing o Stow/Deploy - Test Bed o Life testing o Stow/Deploy o Efficiency	*Sovonics
6. NaS Battery - Zero-G Operation o Wicking in both electrodes - Launch o electrolyte breakage - Environmental interaction o Radiator Surface performance o Internal Thermal Performance (Long Term)	5	- Shuttle Flight o Not Feasible - Test Bed o Launch Inactive, Activate on Test Bed o Performance Verif- ication - Zero G - Radiator Performance - Thermal Performance	*USAF
7. Li/TiS2 Battery - Verification of Performance o Zero Gravity (Long Term) o Launch	3	- Shuttle Flight o Launch o Zero G (Short Term) - Test Bed o Zero G (Long Term)	*JPL

* Inputs Received From Letter Survey

IDENTIFICATION OF PRECURSOR ACTIVITIES (CONT)

Experiment/Measurements	Maturity Level	Tasks To Do	Vendor
8. H_2/Br_2 RFC's - Concept Demonstration - Zero Gravity Operation - Launch Survivability	2	- Technology is not fully conceptualized. o Planning is TBD	
9. NiH_2 Bipolar Battery - Zero-G Operation o Electrolyte wicking - Launch o Electrolyte re-distribution	3	- Shuttle flight o Zero Gravity o Launch survivability - Test Bed o Zero Gravity o Life Testing	* Ford Aerospace
10. H_2O_2 RFC's - Verification of Performance o Zero Gravity o Launch survivability	3	- Shuttle Flight o Zero Gravity (short term) o Launch survivability - Test Bed o Zero Gravity (Long Term) - Life Testing	

* Inputs Received From Letter Survey

IDENTIFICATION OF PRECURSOR ACTIVITIES (CONT)

Experiment/Measurements	Maturity Level	Tasks To Do	Vendor
11. Microwave Power Transmission - Concept Demonstration	1	- Concept is not fully conceptualized o Planning is TBD	
12. ThermoPhotovoltaics - Surface properties o Vaporization of high temperature surfaces o Deposition of materials onto reflective surfaces o Atomic Oxygen Interaction - Solar Cell Technology o Cell design for specific spectral output	1	- Shuttle Flight o Qualification of solar cell technology - Test Bed o Long term performance o materials/surfaces o solar cells	

* Inputs Received From Letter Survey

INDUSTRY CONTACTS

1.	LITHIUM BATTERIES	MR. E.U.COSTOGUE JET PROPULSION LABORATORY SPACE POWER SECTION 4800 OAK GROVE DRIVE PASADENA, CALIF. 91109
2.	AMORPHOUS SILICON	DR. JOSEPH HANAK SOVONICS 6180 COCHRAN ROAD P.O. BOX 39608 SOLON, OHIO 44139
3.	CONCENTRATOR ARRAYS	MR. LIONEL PELENC AEROSPATIALE 100 BOULEVARD DU MIDE BP99 CANNES, FRANCE 06322
4.	SODIUM SULPHER BATTERIES	LT. ROSS DUEBER UNITED STATES AIR FORCE WRIGHT PATTERSON AIR FORCE BASE POWER TECHNOLOGY BRANCH OHIO 45433
5.	PLASMA TESTING	MR. AKIO SUZUKI DIVISION GENERAL MANAGER SHARP ELECTRONICS 2613-1 ICHINOMOTO, TENRI-CITI NARA 632, JAPAN
6.	NICKEL HYDROGEN BIPOLAR BATTERIES	MR. CHARLES KOEHLER FORD AEROSPACE AND COMMUNICATIONS CORPORATION 3939 FABIAN WAY M/S G-45 PALO ALTO, CALIF. 94303

TEST BED RESOURCE REQUIREMENT PLANNING

ENERGY STORAGE EXPERIMENTS

EXPERIMENT POWER RESOURCES (Average Watts)	1994	1995	1996	1997	1998	1999	2000+
SODIUM SULPHER BATTERY	880	880	880				
NICKEL-HYDROGEN BIPOLAR BATTERY			880	880	880		
LITHIUM BATTERY		770	770	770			
HYDROGEN-OXYGEN REGENERATIVE FUEL CELLS						1230	
HYDROGEN-BROMINE REGENERATIVE FUEL CELLS							820
ENERGY WHEELS							720
TOTAL REQUIREMENTS (Watts)	880	1650	2530	1650	880	1230	1540

MAXIMUM POWER SCHEDULED: 2530 WATTS

END DATE MAR. 18, 1987